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New Results and Insight Into Tropospheric Composition - (TES) Tropospheric Emission Spectrometer

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IGARSS August 2, 2006

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Tropospheric ozone and other gases

- The challenge and why
- The how to do ‘it’
- Did ‘it’ work
- What we are trying to do with ‘it’
- What else is happening
- What next

ENVIRONMENTAL IMPACTS OF ATMOSPHERIC OZONE

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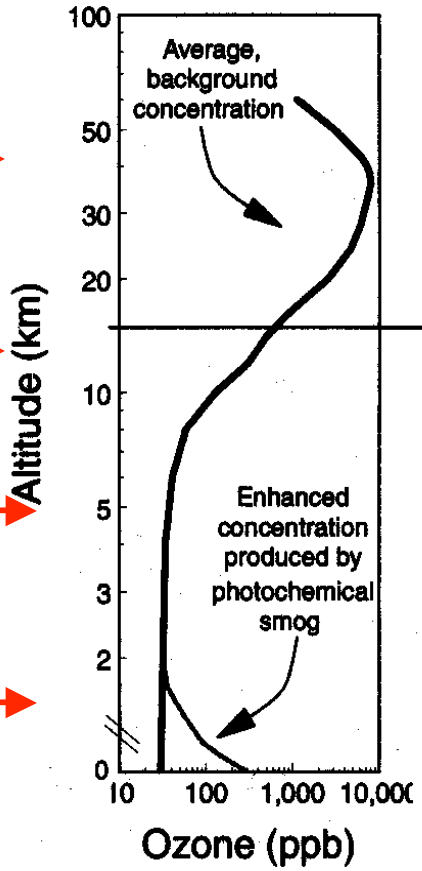
Ozone is..

UV shield →

Greenhouse gas →

Primary source of OH radicals →

Smog →



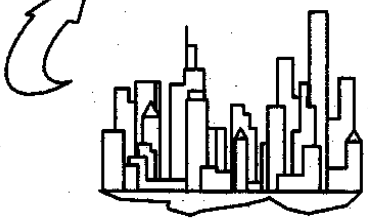
$O_2 + UV\ Sunlight = O + O$

$O + O_2 = O_3$

Stratosphere

Troposphere

CO, VOC } $+ NOx + Sunlight = O_3$



Jacob (Harvard)

Tropospheric ozone and its precursors are a key measure of air quality and the characterization of the chemical and dynamic processes governing their magnitude and distribution is one of the central extant scientific challenges

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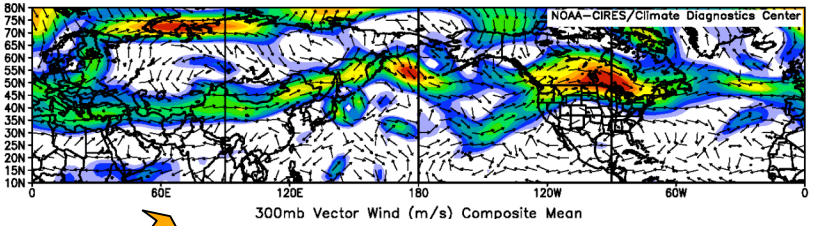
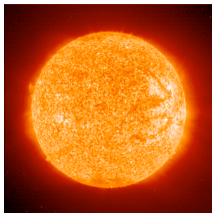
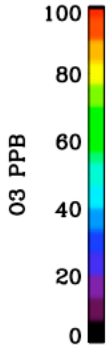
Anthropogenic sources

Natural sources

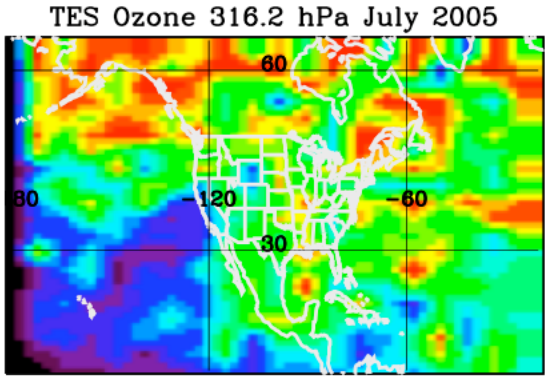




Solar radiation



Advection



Subsidence

Convection

Spectrometer

Characterization of the vertical distribution of ozone is critical to understanding its role in air quality and climate

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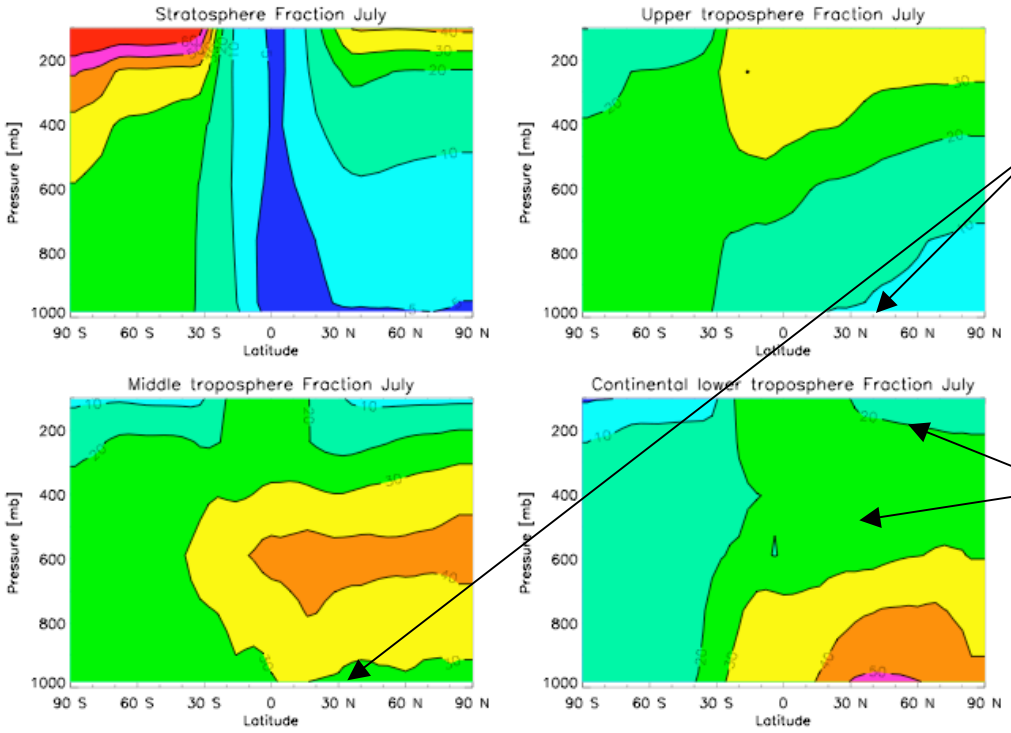
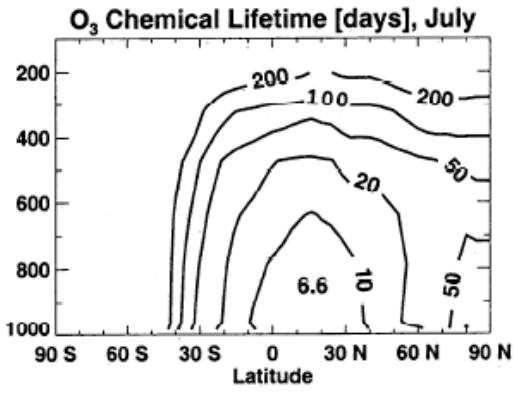


10% and 20% of lower tropospheric ozone originates from the upper and middle troposphere in the northern mid-latitudes

20-30% of the lower tropospheric ozone reaches the upper and middle troposphere in the northern mid-latitudes

Y. Wang et al, JGR 1998

Fractional contribution of source regions to zonal mean ozone distribution for a GEOS-Chem simulation for a climatological period



The lifetime of ozone is strongly dependent on its altitude

Driving requirements

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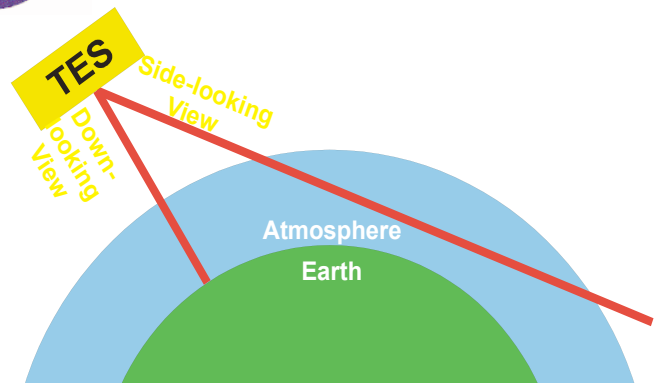
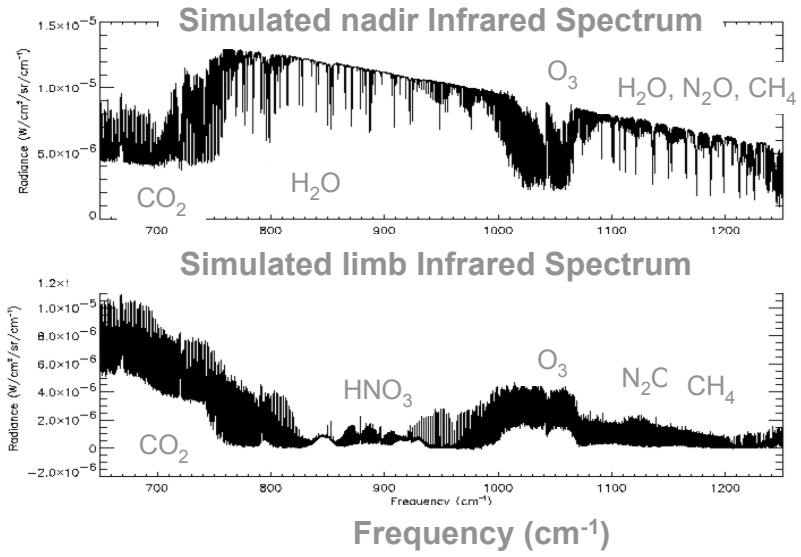
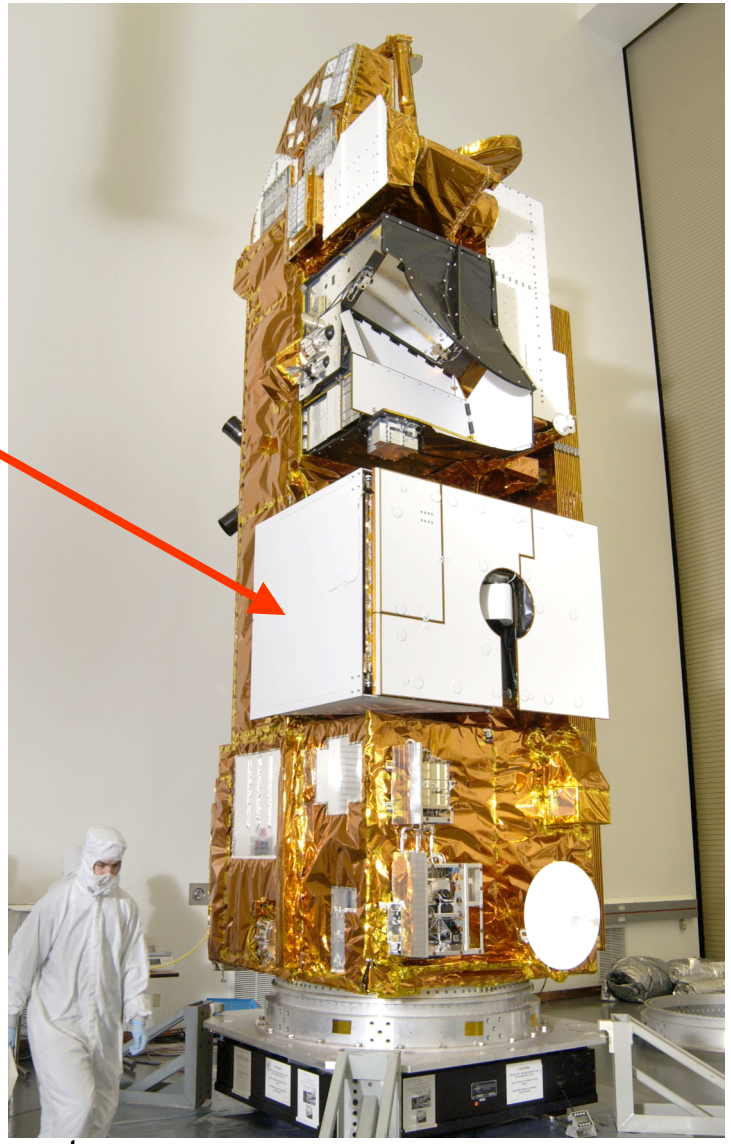
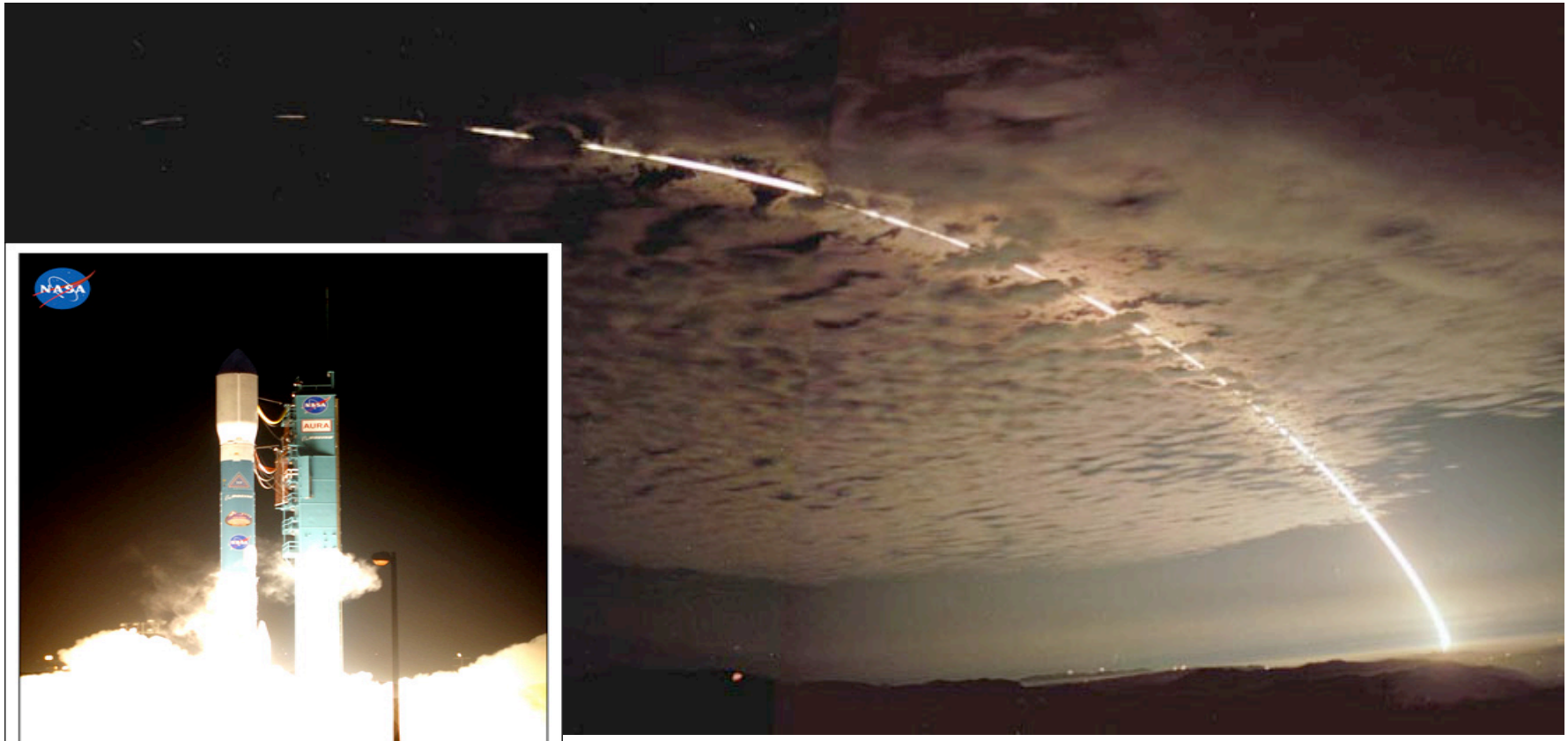




Spectrometer Type	**Connes'-type 4-port FTS**
Max. Optical Path Difference	**± 8.45 cm (nadir & calibration)** **± 33.8 cm (limb)**
Scan (integration) Time	**4 sec (nadir & calibration)** **16 sec (limb)**
Sampling Metrology	**Nd:YAG laser**
Spectral Resolution (unap)	**0.07 cm^{-1} (nadir)** **0.018 cm^{-1} (limb)**
Spectral Coverage	**650 to 3050 cm^{-1}** **(3.2 to 15.4 mm)** **in 200 – 300 cm^{-1} bands**
Detector Arrays	**4 (1 x 16) arrays, optically-conjugated, all MCT PV @65K**
Signal-to-Noise Ratio (spectral)	**Up to 200:1** **Minimum requirement is 30:1**
Radiometric Calibration	**Internal, adjustable, cavity blackbody (340K) + cold space view**
Spatial Calibration	**Illuminated slit scanned across FOV**
Radiometric Accuracy	**< 1K 650 – 2500 cm^{-1}** **< 2K 2500 – 3050 cm^{-1}**



- Fourier transform spectrometer
- Wavelength response: 5 to 15.4 micron
- One scan every 4 or 16 secs
- Four optically-conjugated 1x16 pixel detector arrays
- Spatial resolution of 5 x 8 km at nadir & 2.3 km at limb
- Passively cooled
- 2-axis gimbaled pointing mirror



July 15, 2004

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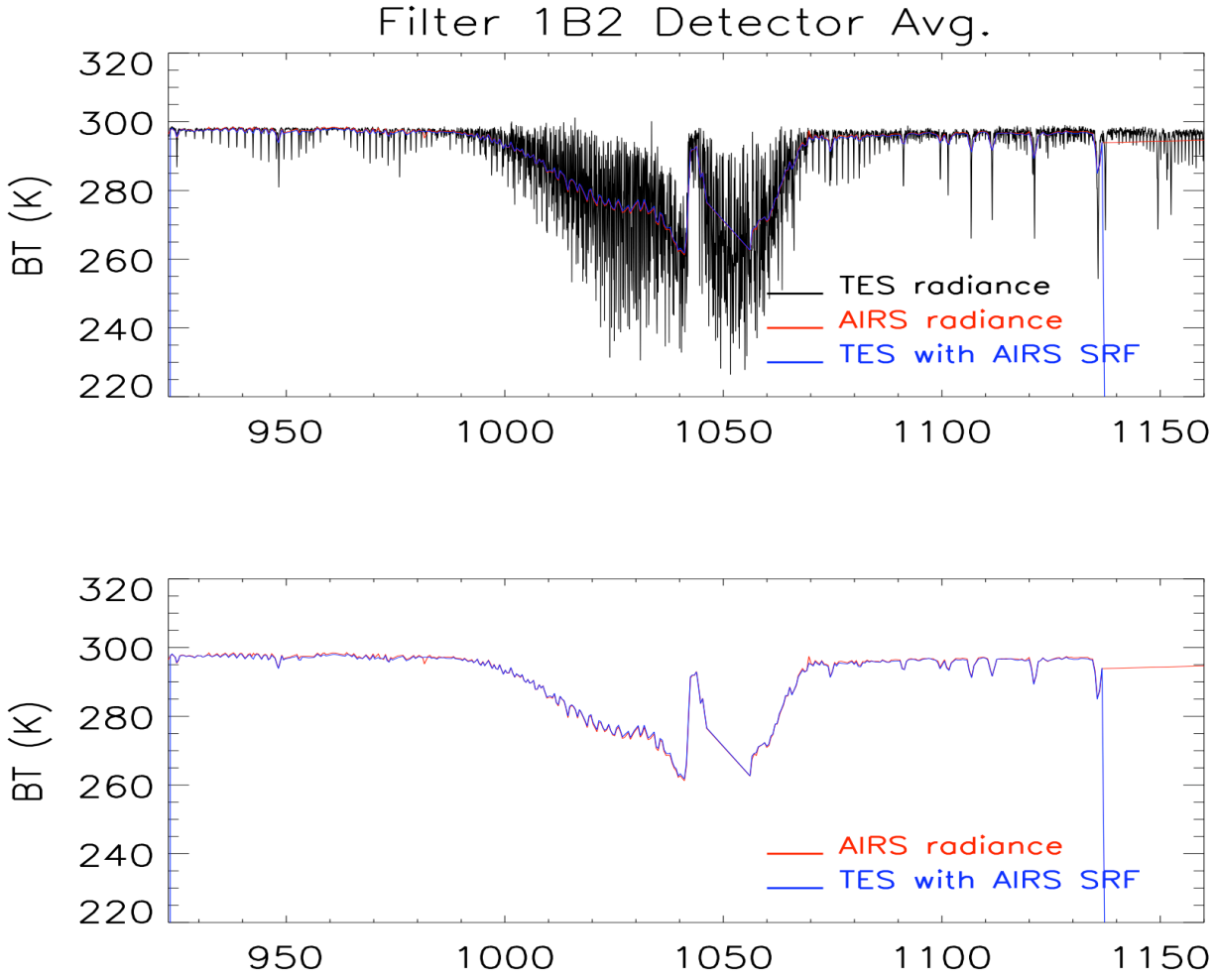
Tgt_Spectrum_Run0000003202_Seq0000023_Scan000003



First look……..

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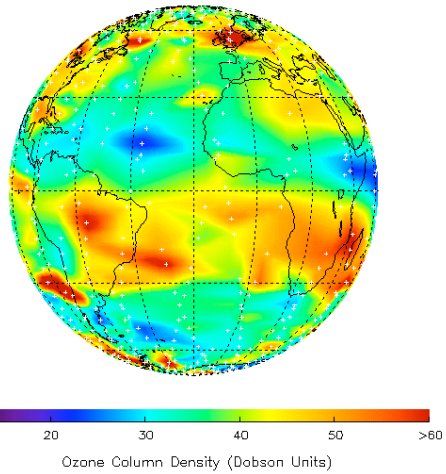
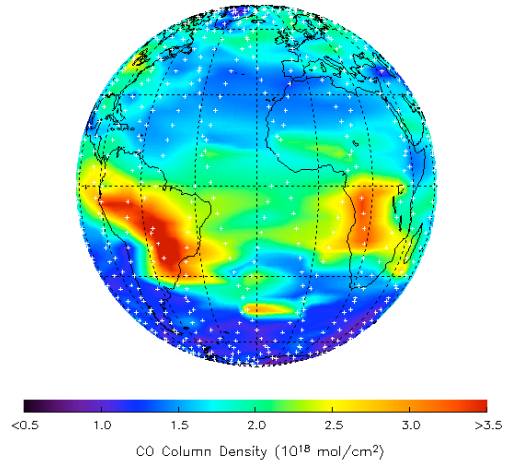
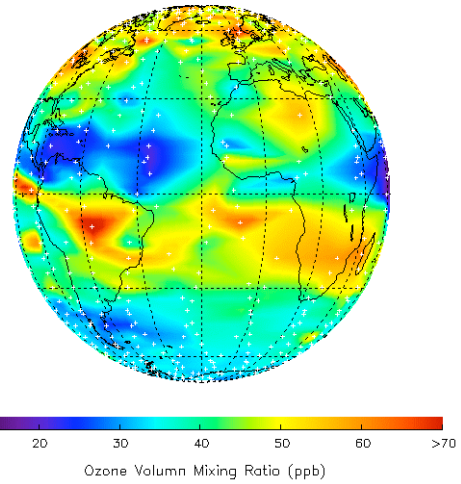
TES Level3 Image: Ozone, Run=2147, Trop Col Density (DU)
Min Value = 8.5 DU, Max Value = 193.7 DU, Using Along Orbit Interpolated L2 Data



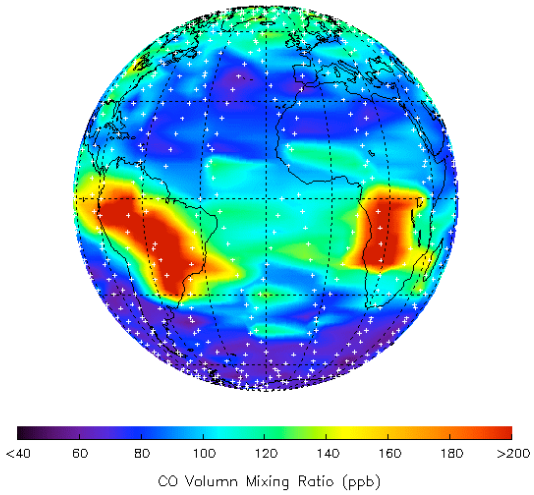
TES Level3 Image: CO, Run = 2147, Trop Col Density (10^{18} mol/cm^2)
Min Value = 0.64X10^{18} mol/cm^2, Max Value = 4.52X10^{18} mol/cm^2, Using Along Orbit Interpolated L2 D



TES Level3 Image: Ozone, Run=2147, Pressure = 681.3 hPa
Min Value = 5.1 ppb, Max Value = 78.2 ppb, Using Along Orbit Interpolated L2 Data



TES Level3 Image: CO, Run = 2147, Pressure = 681.3 hPa
Min Value = 44.1 ppb, Max Value = 421.1 ppb, Using Along Orbit Interpolated L2 Data



Ozonesondes

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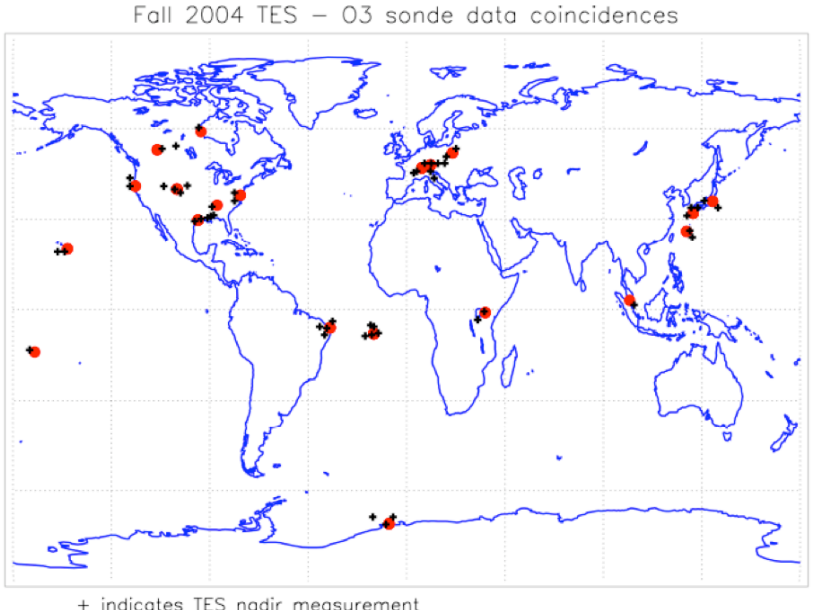
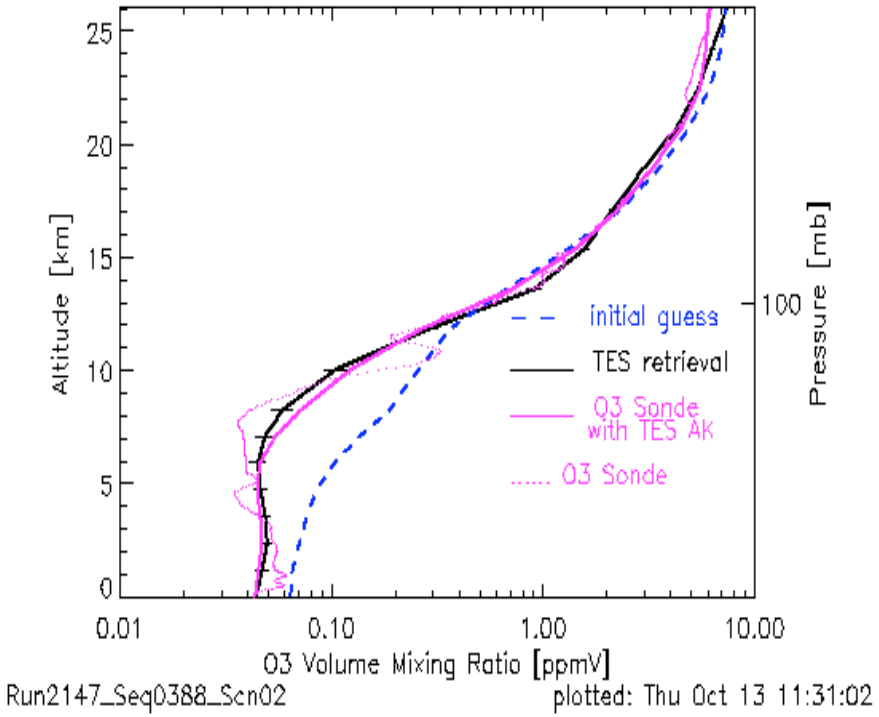


Payerne (47 ° N, 7° E)



H. Worden and Logan

Tropical Tropospheric Ozone Column : Comparison between TES, GEOS-CHEM and GOME

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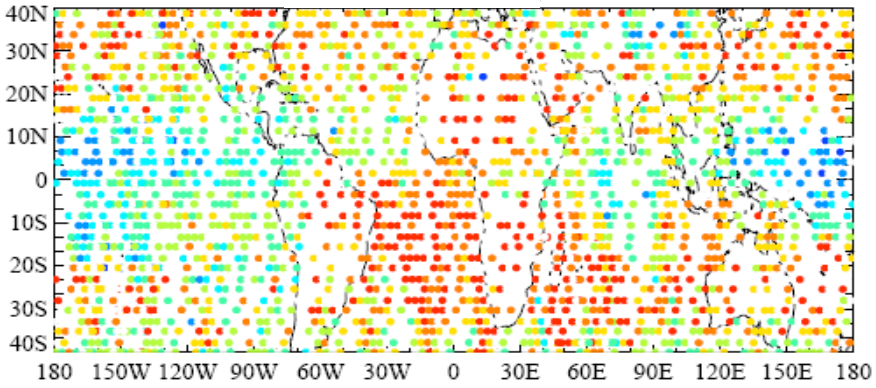
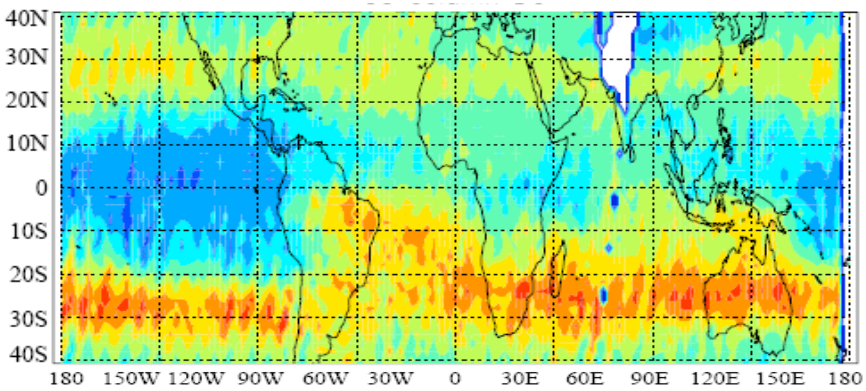
Tropospheric Column

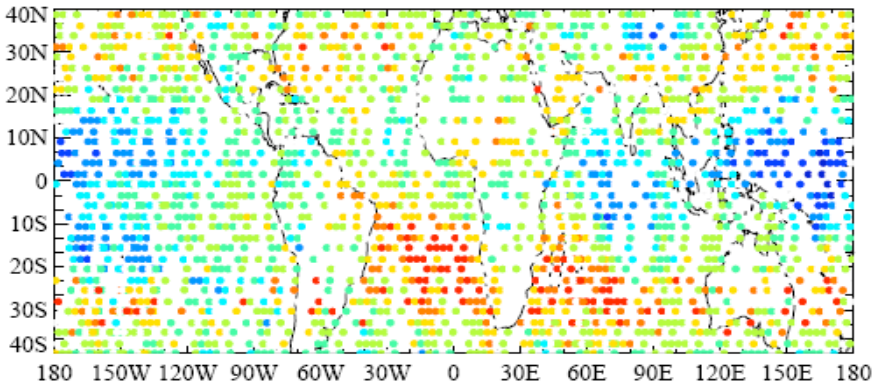


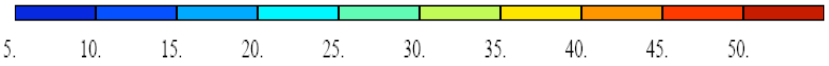
TTOC GOME (DU) Nov. 1997

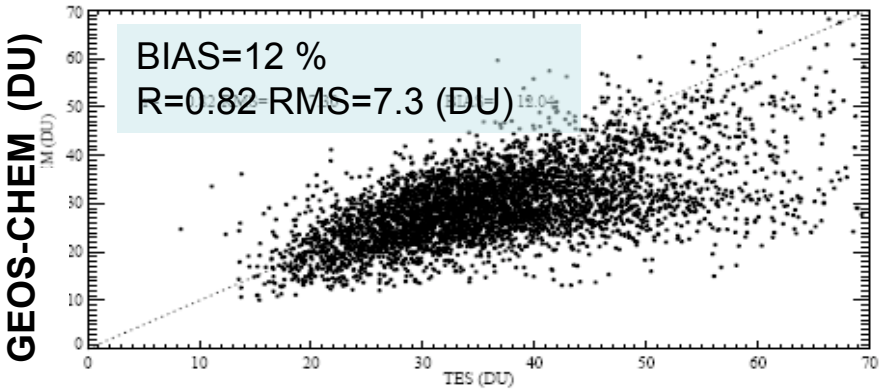


GOME data from Liu et al. 2005

GEOS-CHEM TOC DU







Jourdain and Li

Comparison TES and GEOS-CHEM
1-15 November 2004, 350hPa

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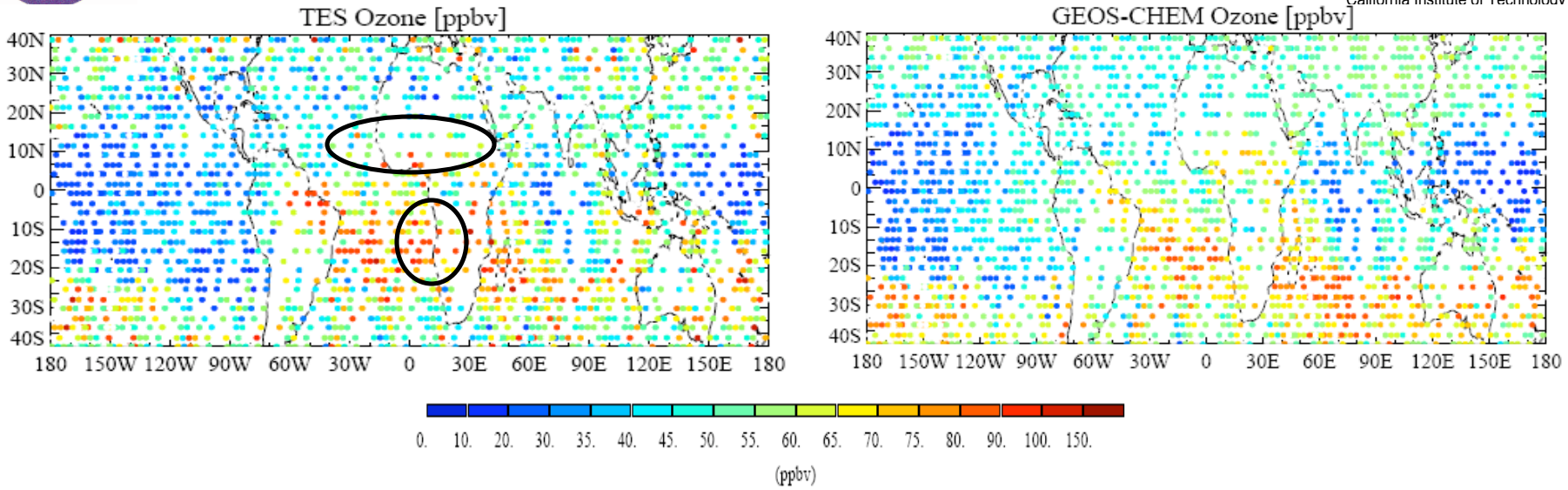
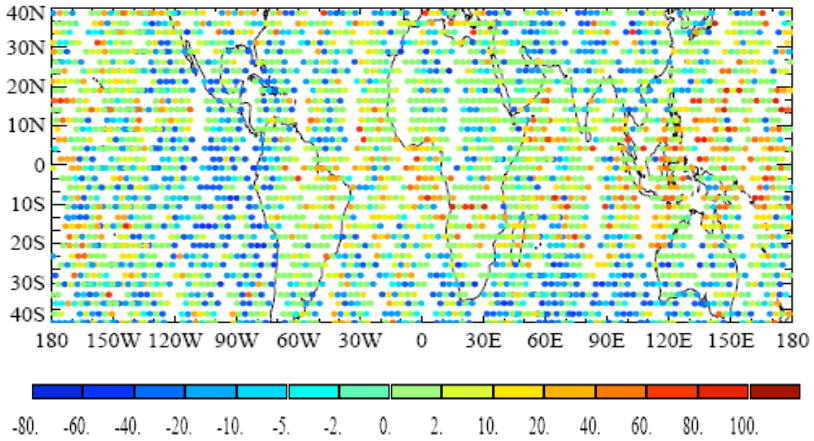
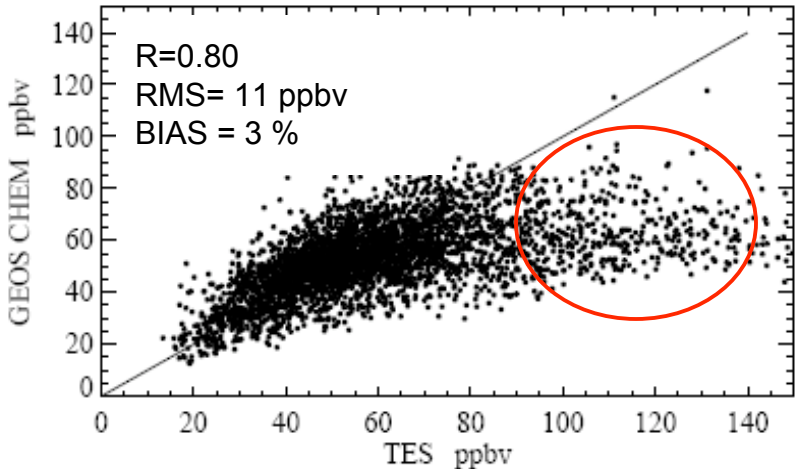


(TES-GEOS_CHEM)/GEOS-CHEM%



Tropics (30N-30S)



Tropical Atlantic 'Ozone Paradox'

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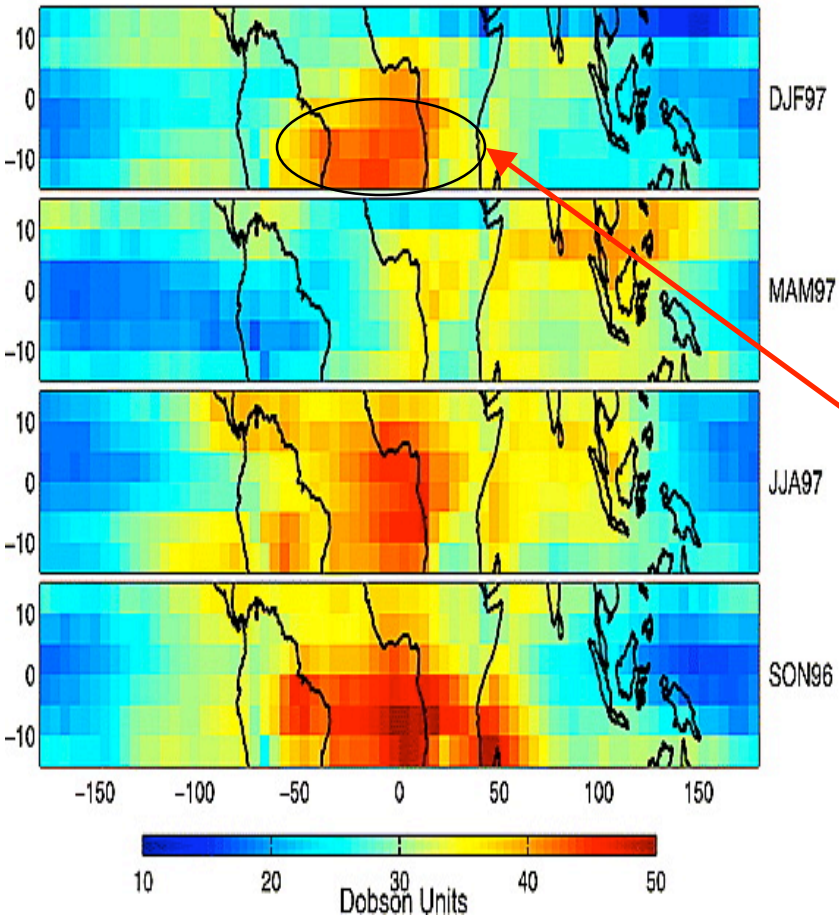
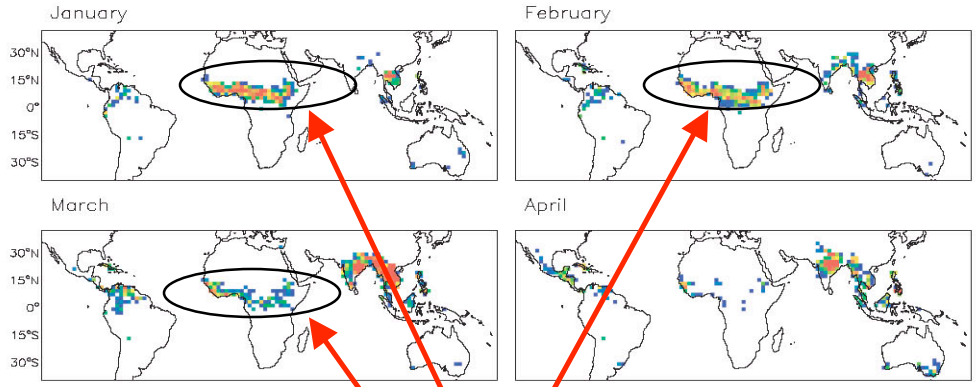
TOMS Tropospheric Ozone Columns
(Martin et al., 2002)



Biomass burning emissions
(Duncan et al., 2003)



Highest TOCs observed by TOMS over the Southern tropical Atlantic in DJF while the biomass burning occur north of the ITCZ [Thompson et al., GRL, 2000]

Tropical Atlantic 'Ozone Paradox'

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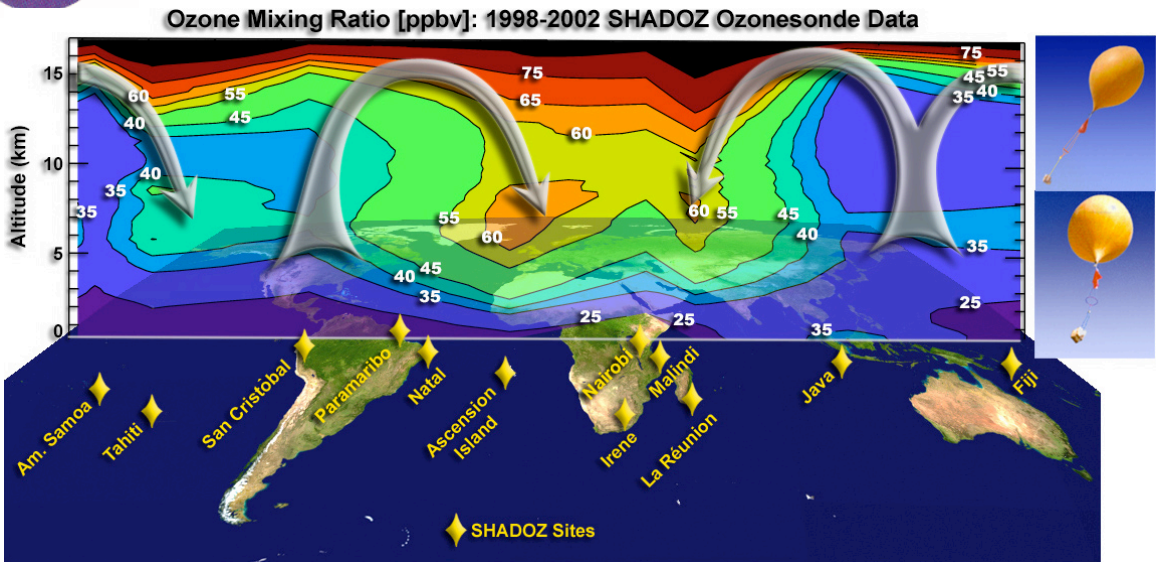
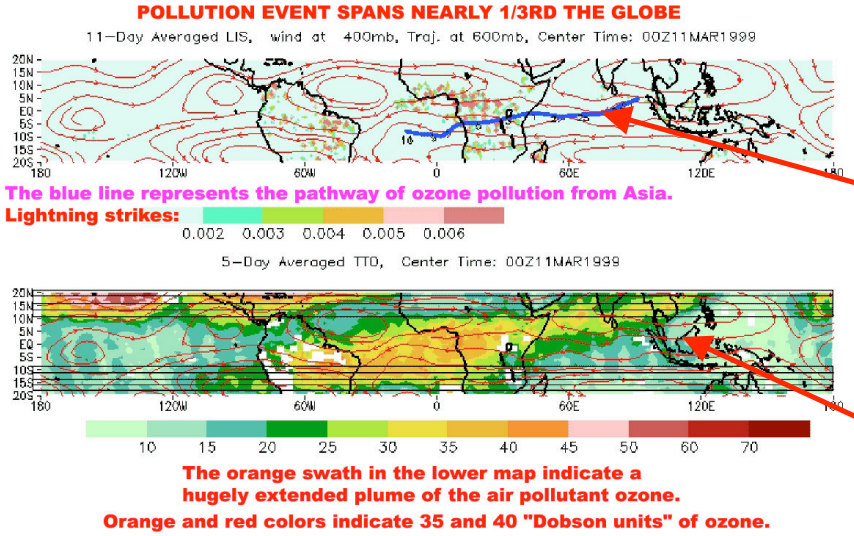


February - March

Adding another factor to the South Atlantic 'Ozone Paradox'



Pathway of Asian ozone pollution

Tropical Tropospheric Ozone (TTO)

Chatfield et al., GRL 2003

Tropical Ozone Paradox Resolved

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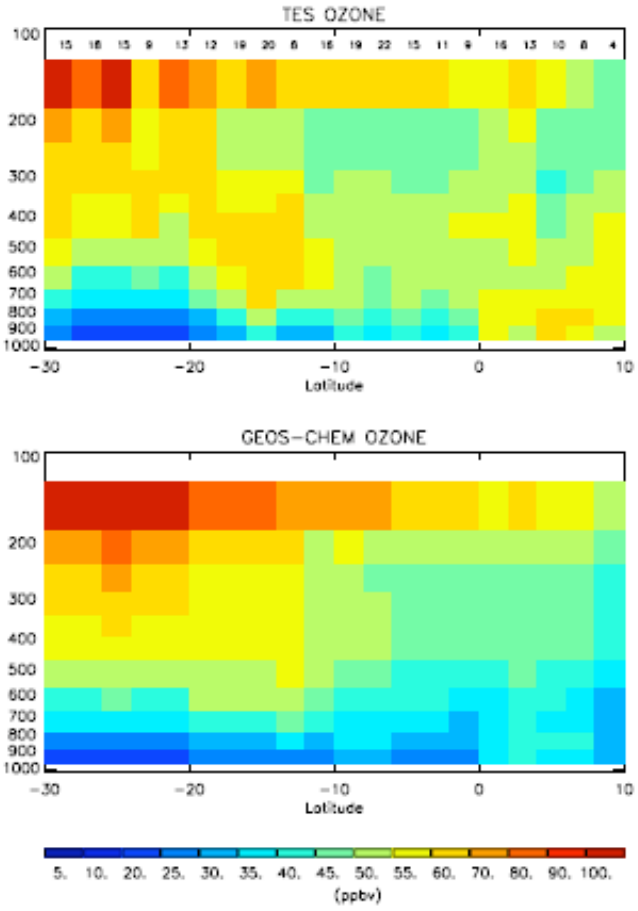
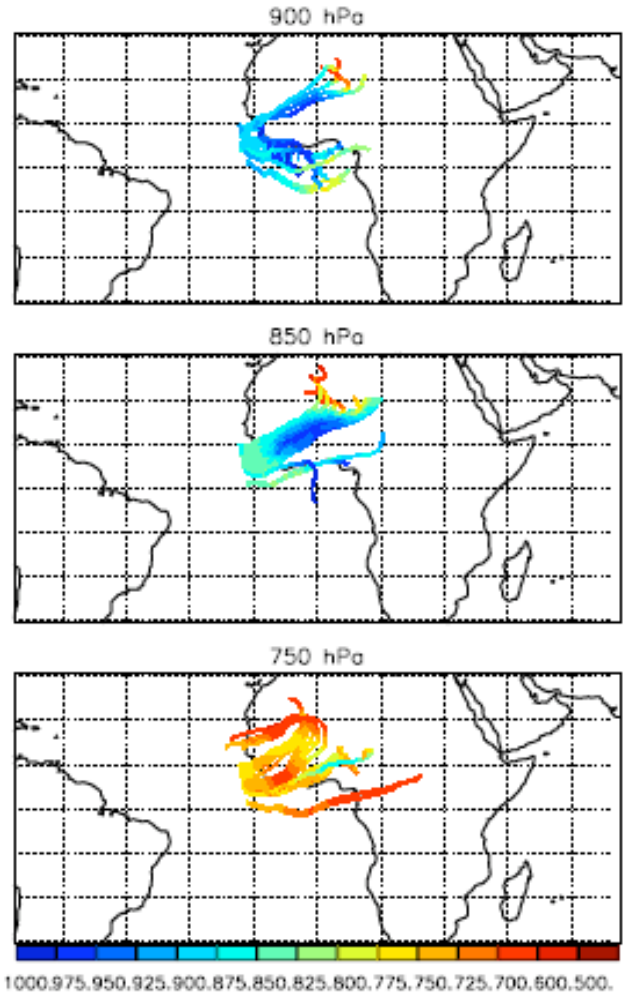
TES tropical Atlantic observations of ozone



GEOS-CHEM predictions of ozone

- There is a long standing difference between balloon/ *in-situ* observations of ozone and ozone columns from instruments such as TOMS
- TES provides the first observation from space resolving lower and upper tropospheric ozone over the Tropical Atlantic Ocean during the Northern Africa biomass burning season.
- TES observations shows the elevated ozone north of the equator which corresponds to the Hartmattan winds that bring dust off the Sahara as well as biomass emissions.

Trajectories show how air is brought off of African coast



August 2, 2006

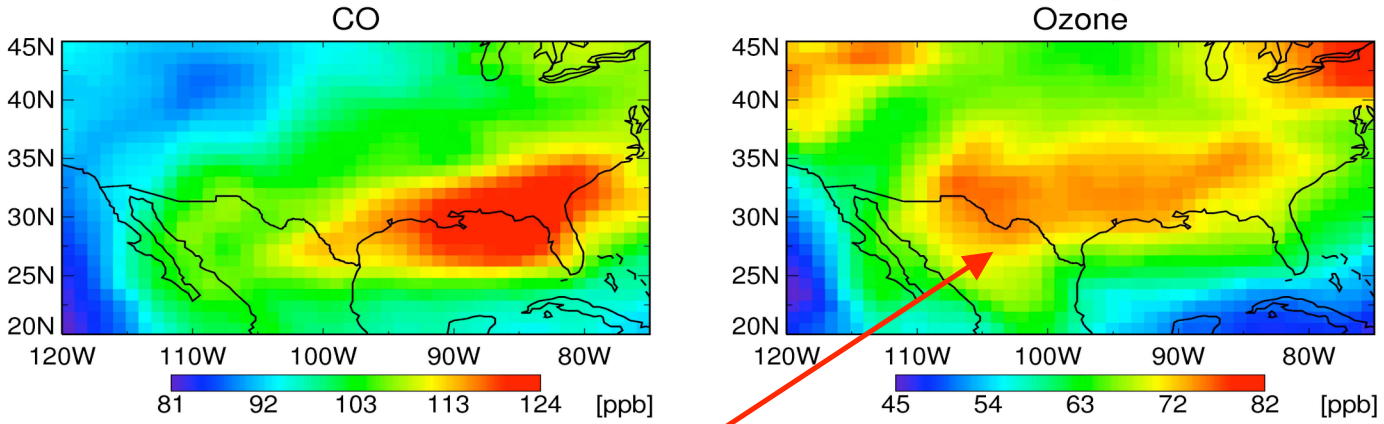
Tropospheric Emission Spectrom

L. Jourdain and H. Worden

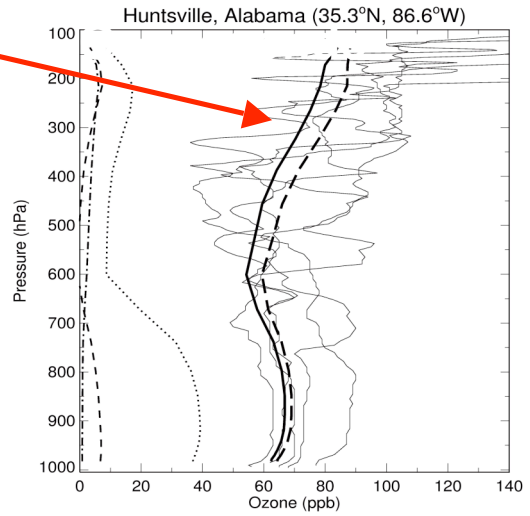
Summertime Ozone Maximum over the Southern U.S.

Jet Propulsion Laboratory
tute of Technology

GEOS-CHEM CO and ozone concentrations, 300 hPa, July 2000



A large maximum in ozone (>80 ppb) in the upper troposphere across the southern U.S. The upper tropospheric anticyclone centered over the southern U.S. can circulate convective outflow over the U.S. for several days before eventual export to the Atlantic. Rapid ozone production (up to 10 ppb/day) takes place in the circulating outflow.



Li et al. [JGR, 2005]

Evolution of ozone through SE North America

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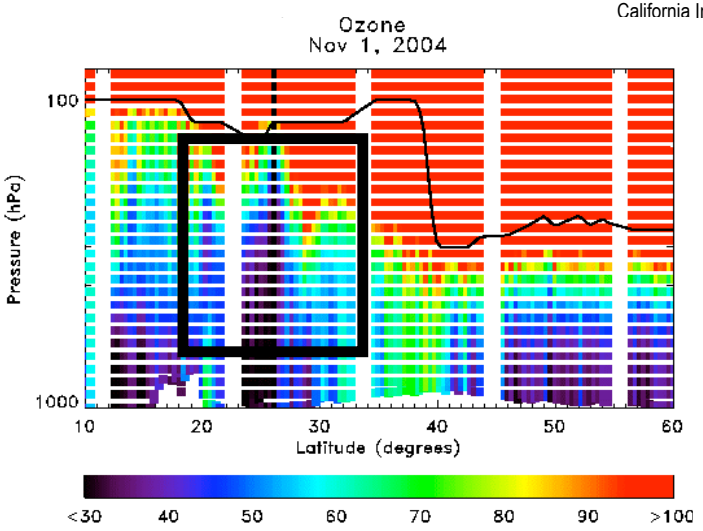
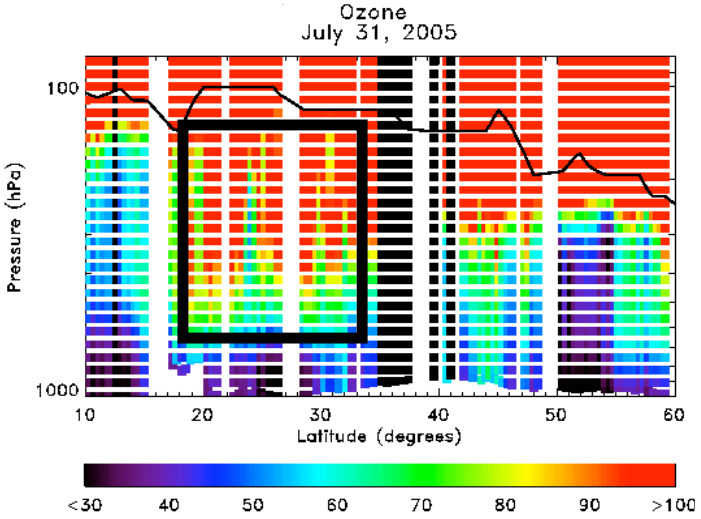
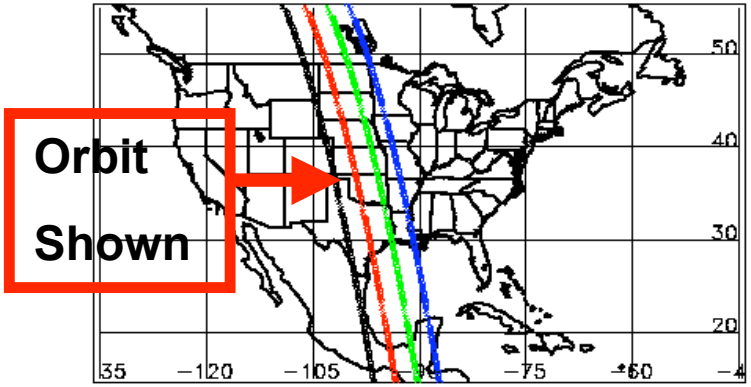
Enhanced ozone in the troposphere over Eastern Mexico, South Texas and the Gulf of Mexico (~20-30° N) in Summer of 2005. The differences are seen in both the upper and lower troposphere.







Assimilation of TES CO into the GEOS-CHEM CTM

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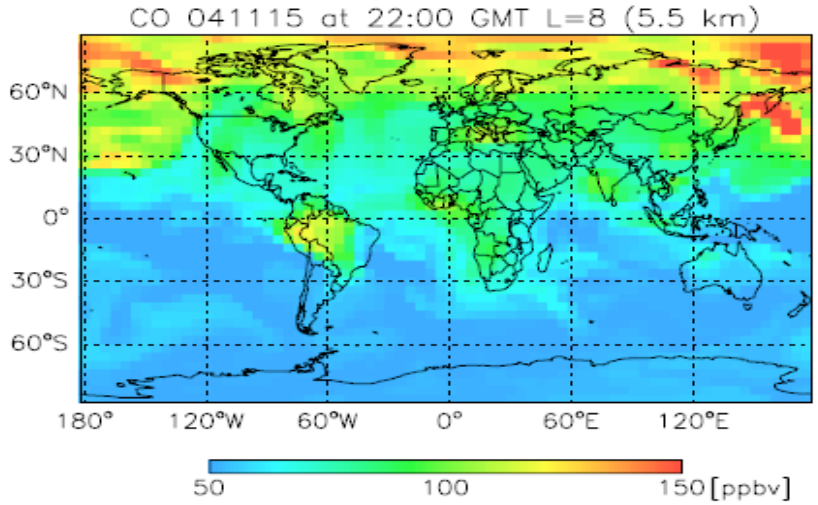
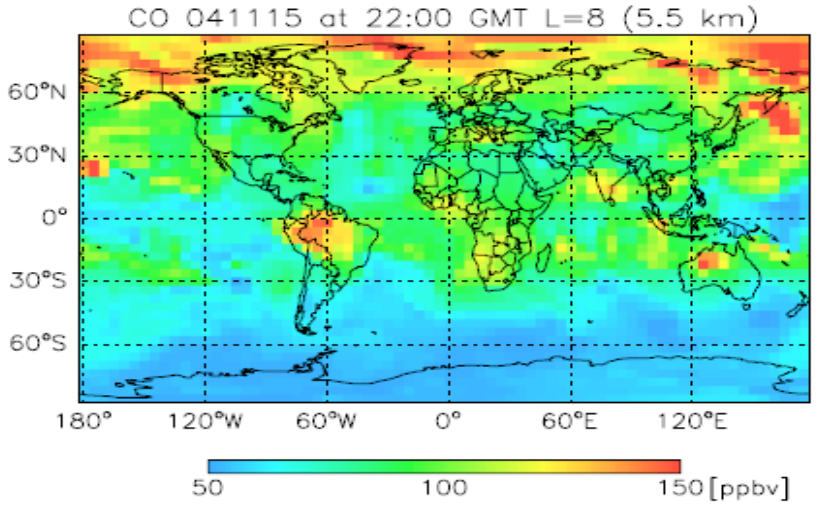
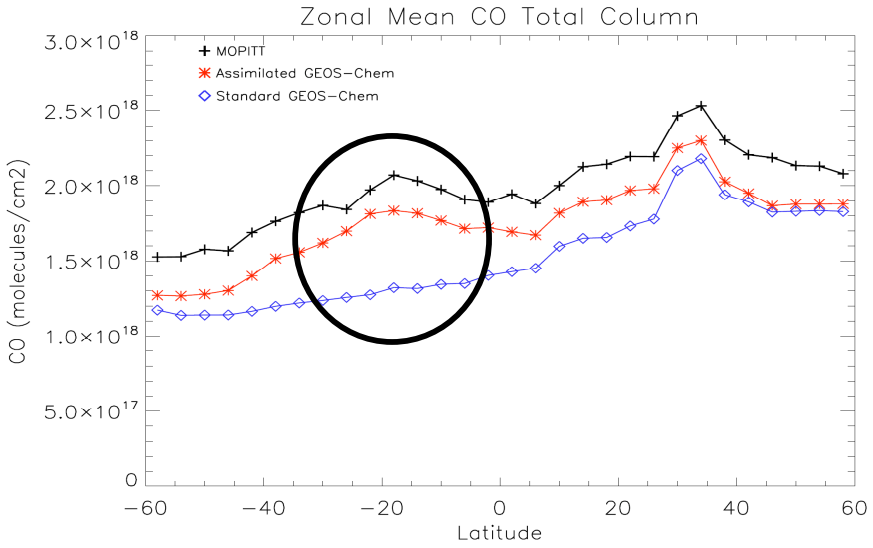
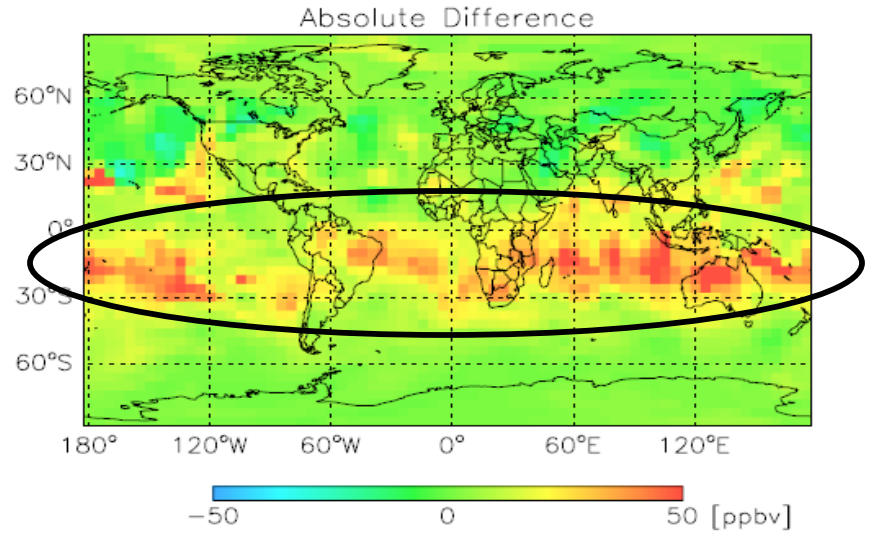
Without Assimilation



With Assimilation

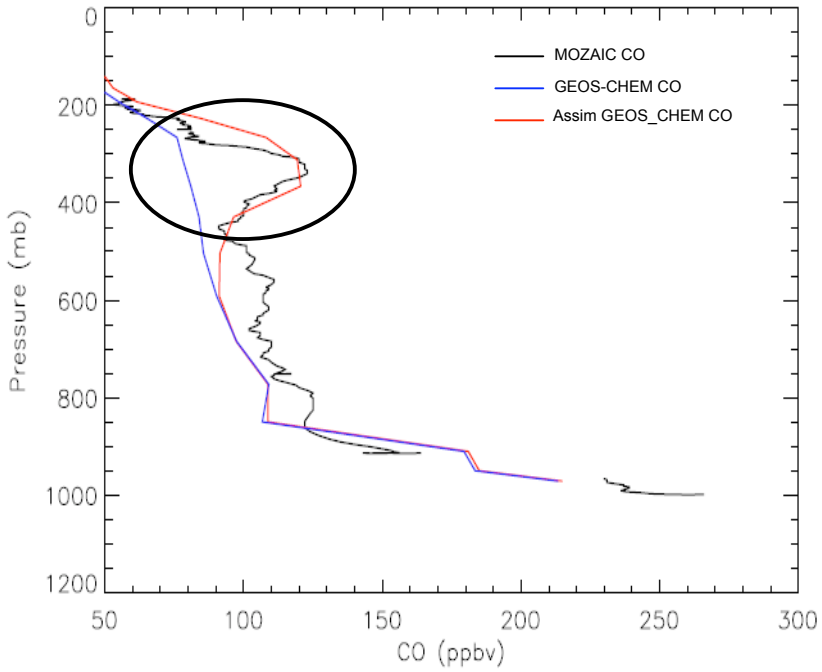


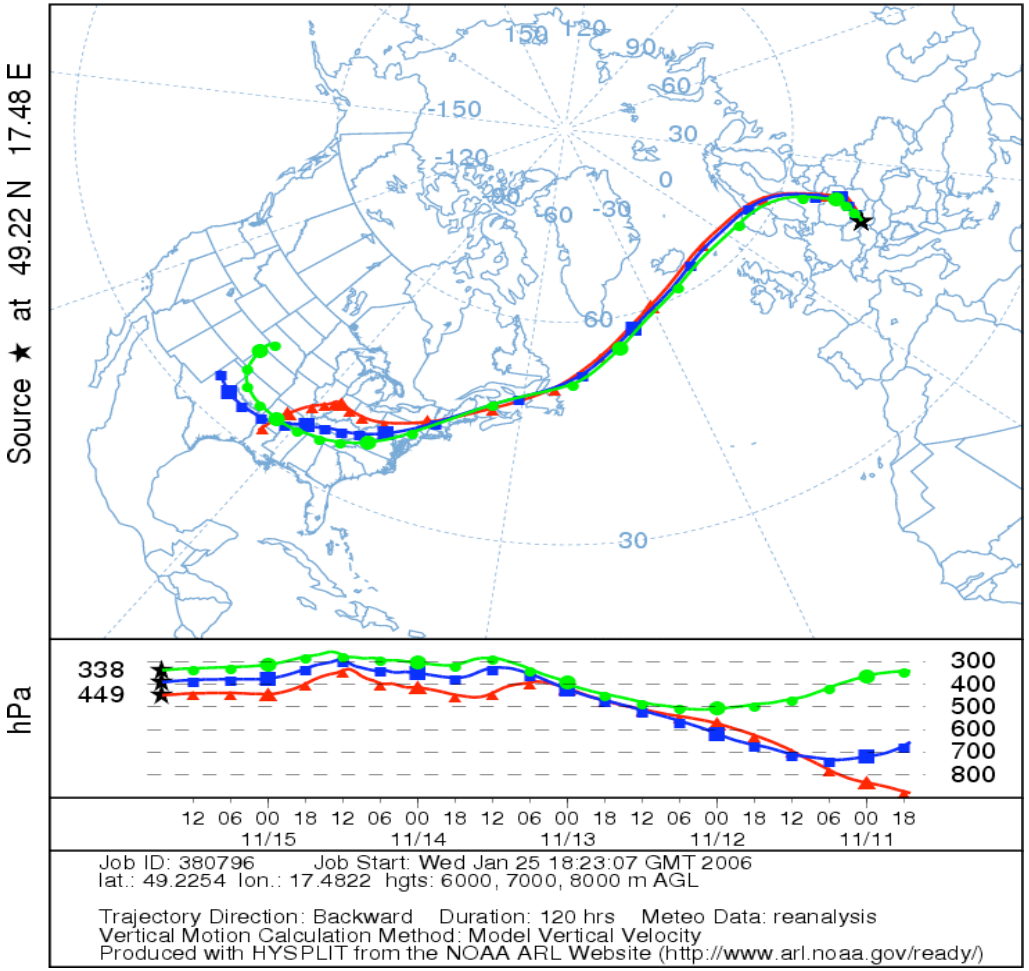




Richards and Li

Assimilation of TES CO into the GEOS-CHEM CTM





Richards and Li

For more info and links to data centers:

tes.jpl.nasa.gov

Backup Slides

TES O3 and CO maps for November 4-16

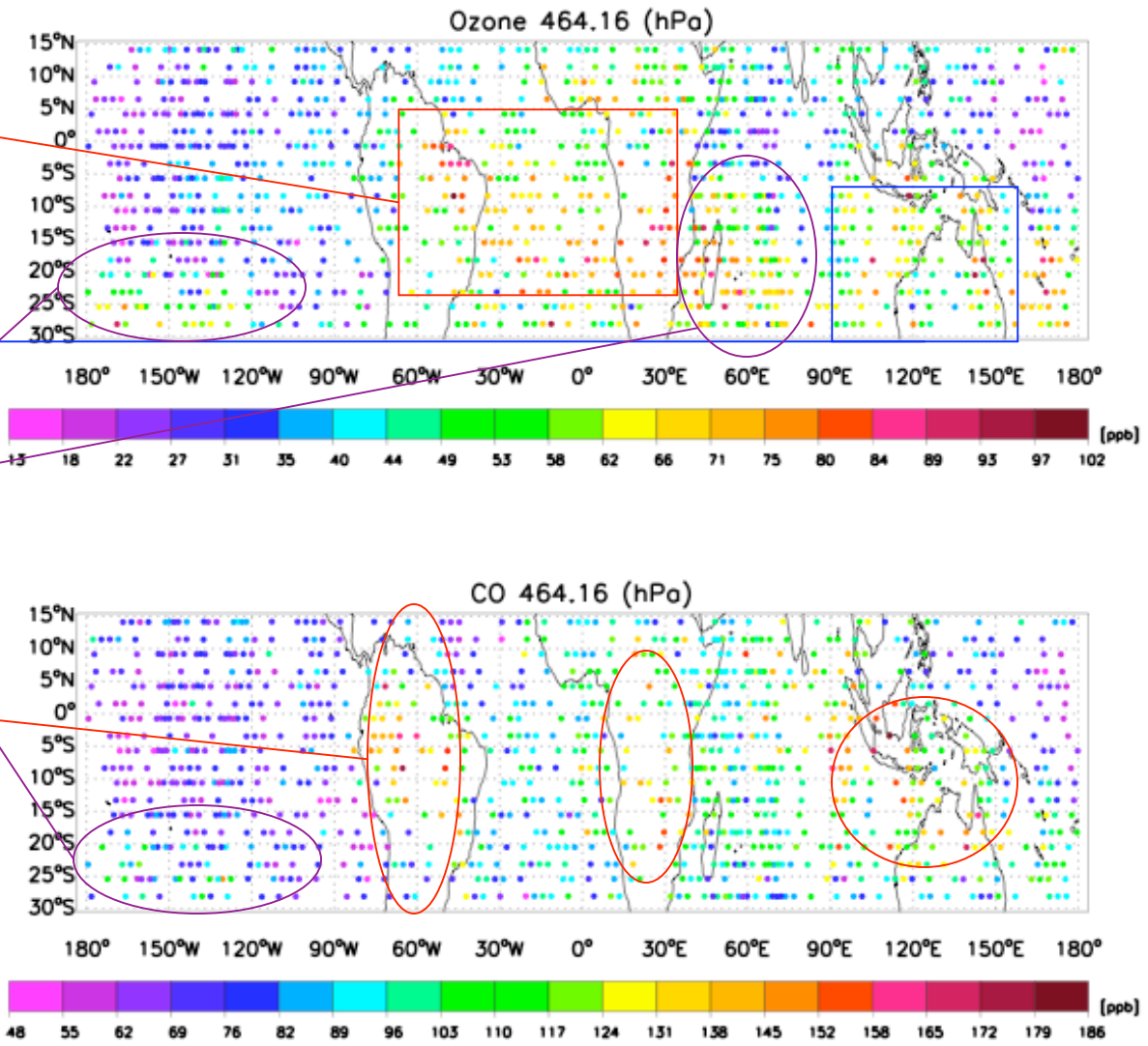
Jet Propulsion Laboratory

Elevated ozone over Atlantic

Elevated ozone over Indonesia/Australia

Transport from Africa and/or Australia?

Elevated CO over continents



Bowman

Signatures of biomass burning

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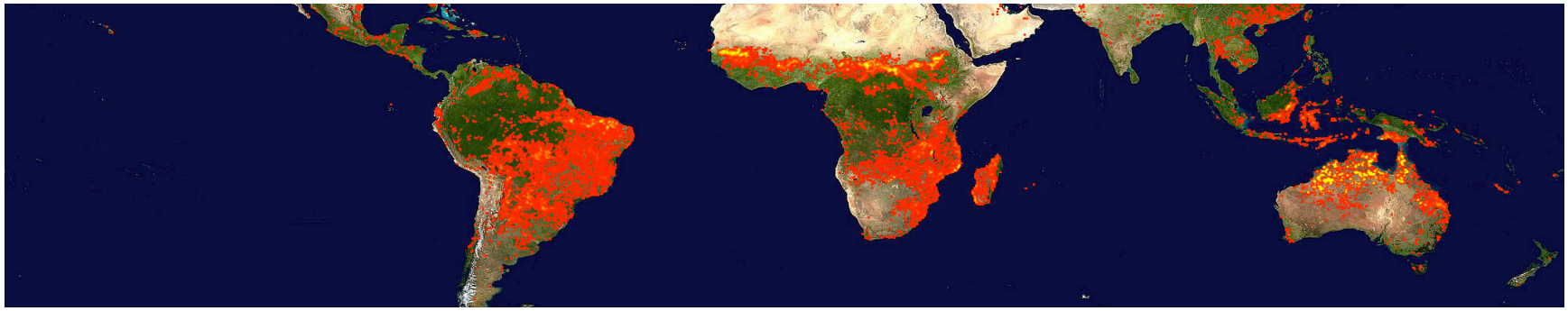
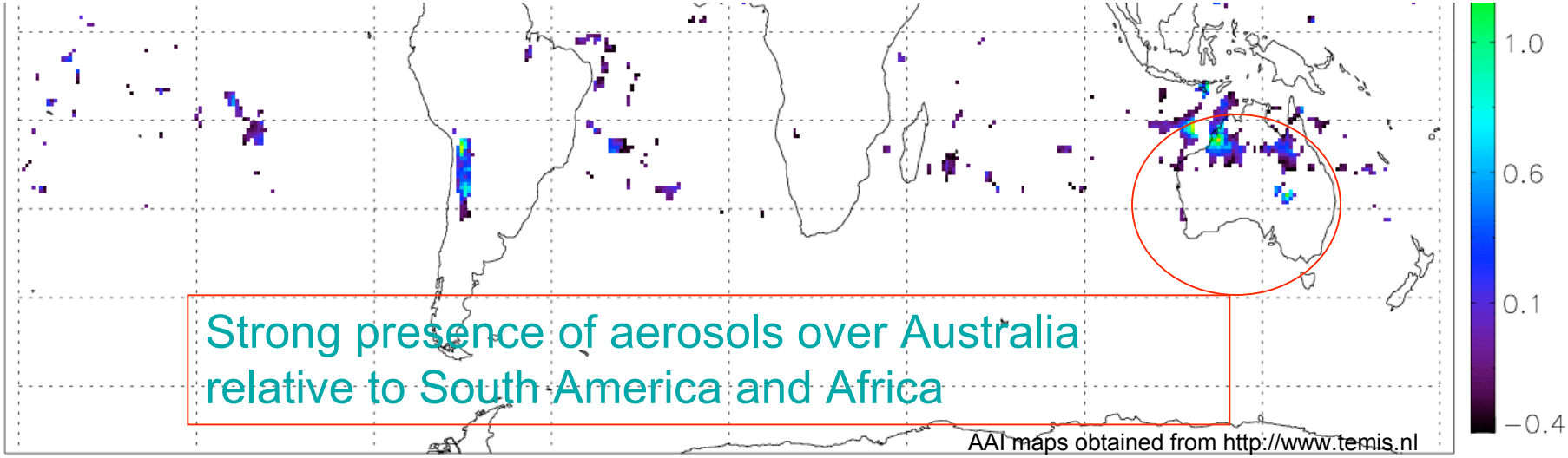
MODIS fire counts November 5-15



Red indicates at least one fire count
Yellow indicates a large number of fire counts

MODIS map obtained from
http://rapidfire.sci.gsfc.nasa.gov/firemaps/?2005211-2005220

Sciamachy absorbing aerosol index (AAI) November 2004



AAI maps obtained from http://www.temis.nl

Bowman

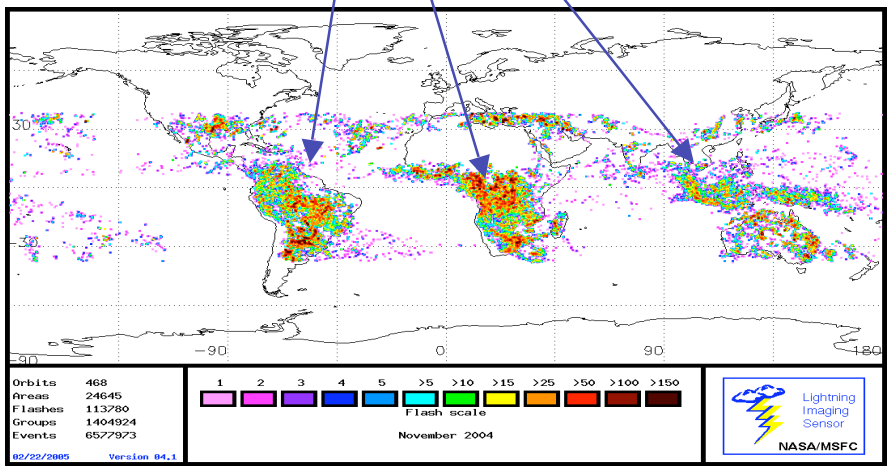
NO_x signatures and distributions

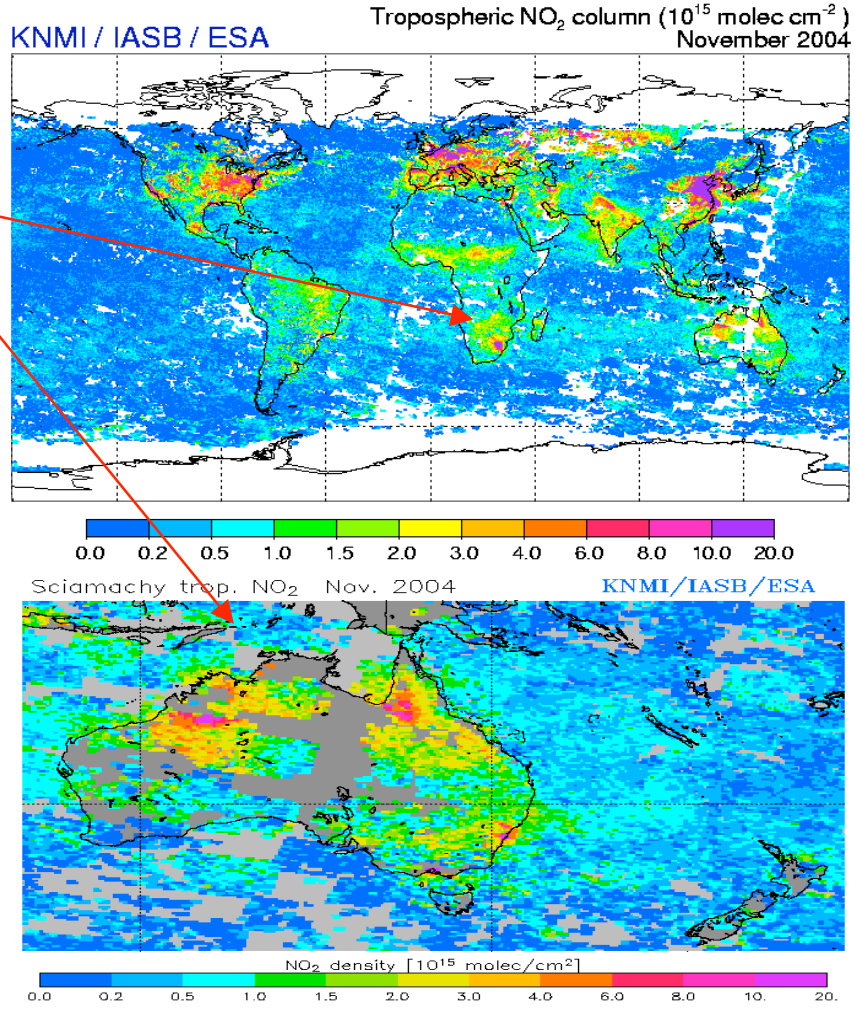
Jet Propulsion Laboratory
California Institute of Technology

Sciamachy data indicates particularly high NO_2 columns in Australia and South Africa

Lightning flash counts are high over South America, Africa, and Indonesia/Australia

http://thunder.msfc.nasa.gov/data/query/distributions.html



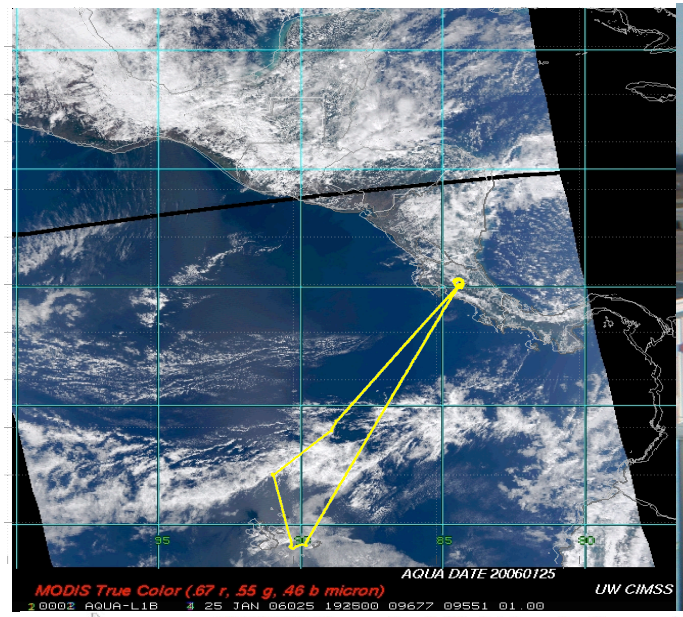


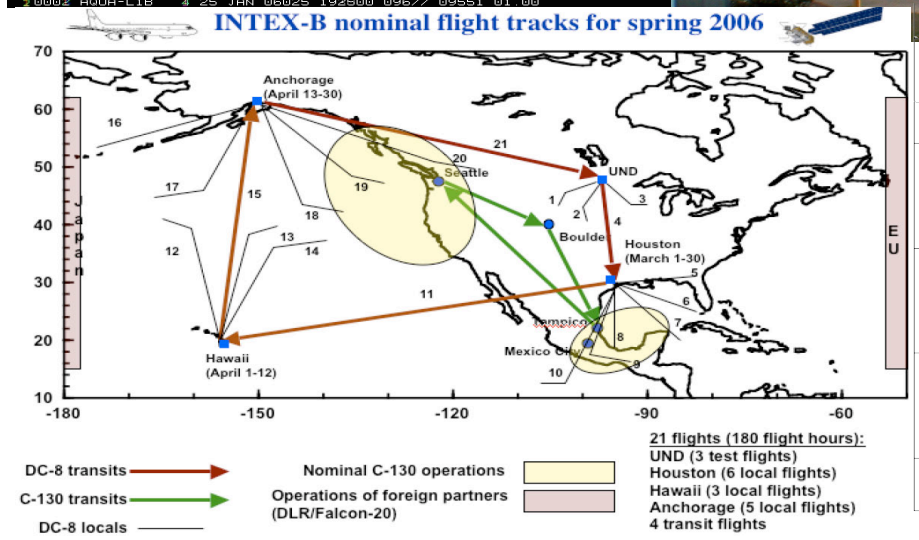
Sciamachy data available at http://www.temis.nl/airpollution/no2.html

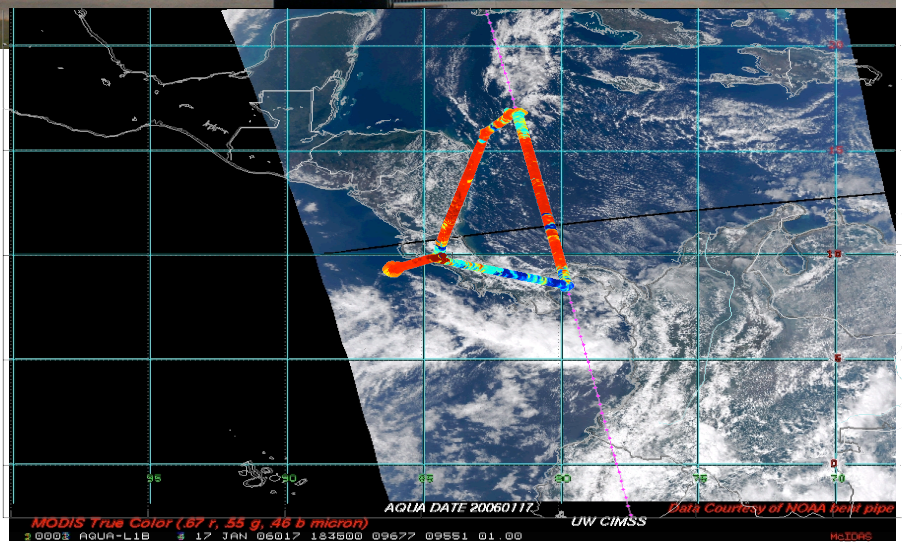
Bowman

CR-AVE and INTEX-B

Jet Propulsion Laboratory
California Institute of Technology



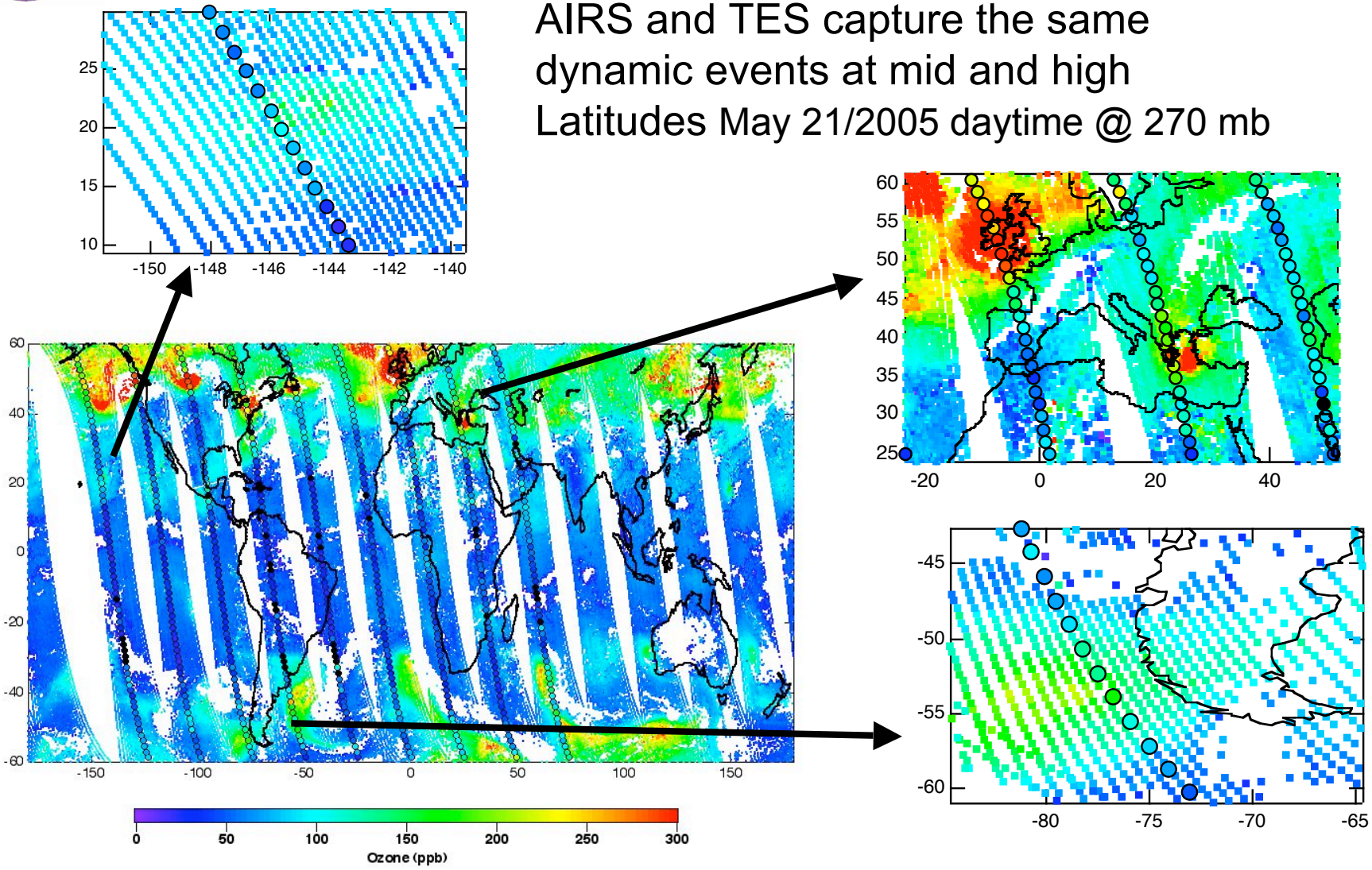




Dynamics and STE

Jet Propulsion Laboratory
California Institute of Technology

AIRS and TES capture the same dynamic events at mid and high Latitudes May 21/2005 daytime @ 270 mb

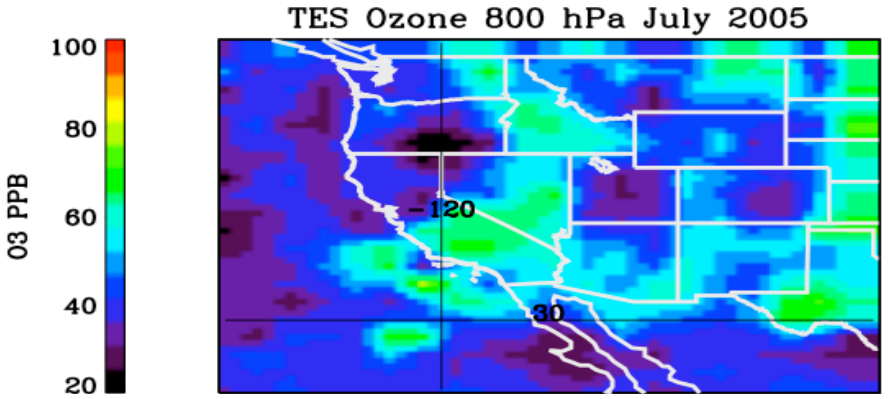


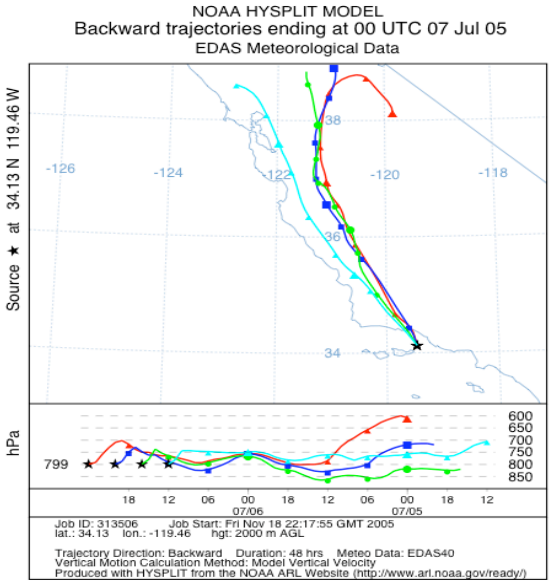
Irion et al.

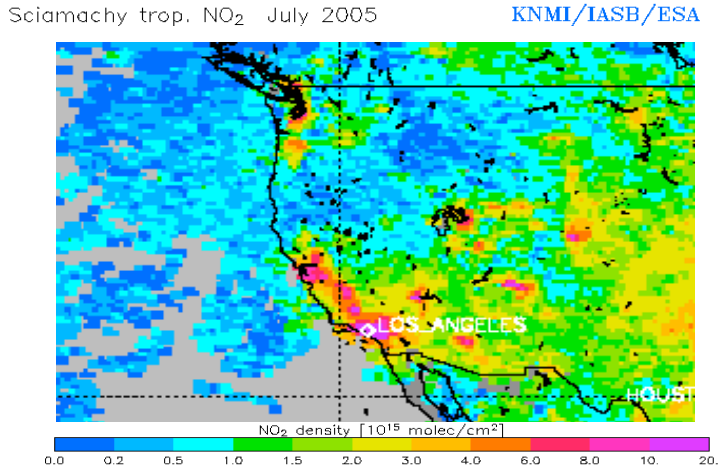
Off-shore ozone plume in California coastal regions

Jet Propulsion Laboratory
California Institute of Technology

Wind fields implicate central valley pollution as a primary contributor to coastal plume





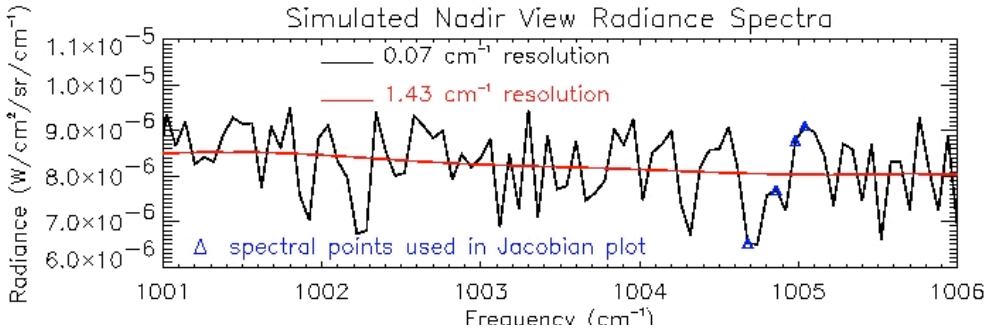


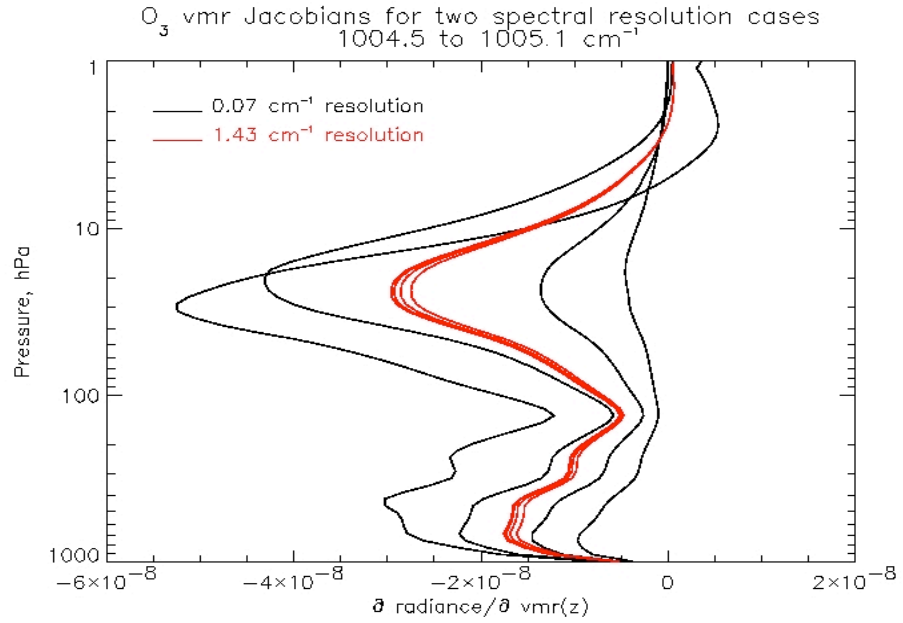
Ozone precursor NO2 observed by Sciamachy to be high throughout urban areas and central valley

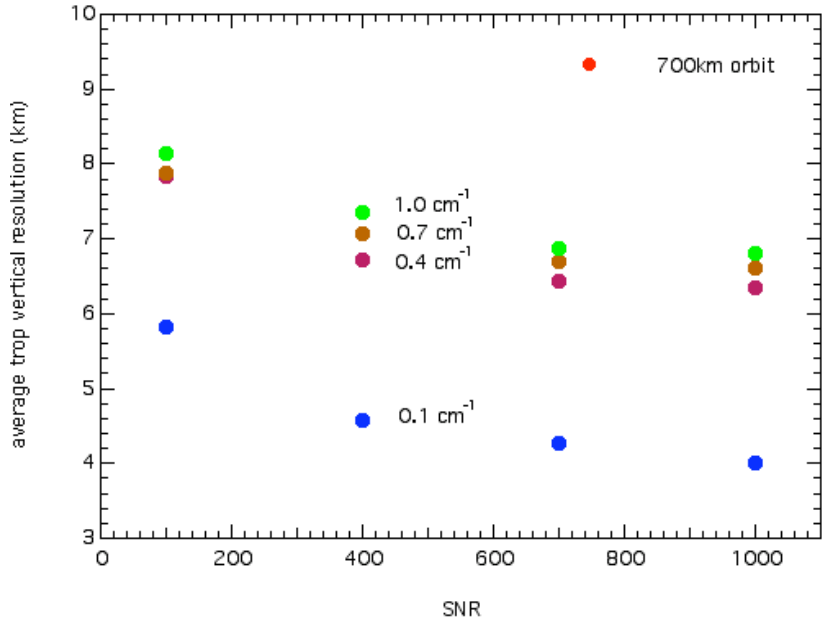
J. Worden et al.

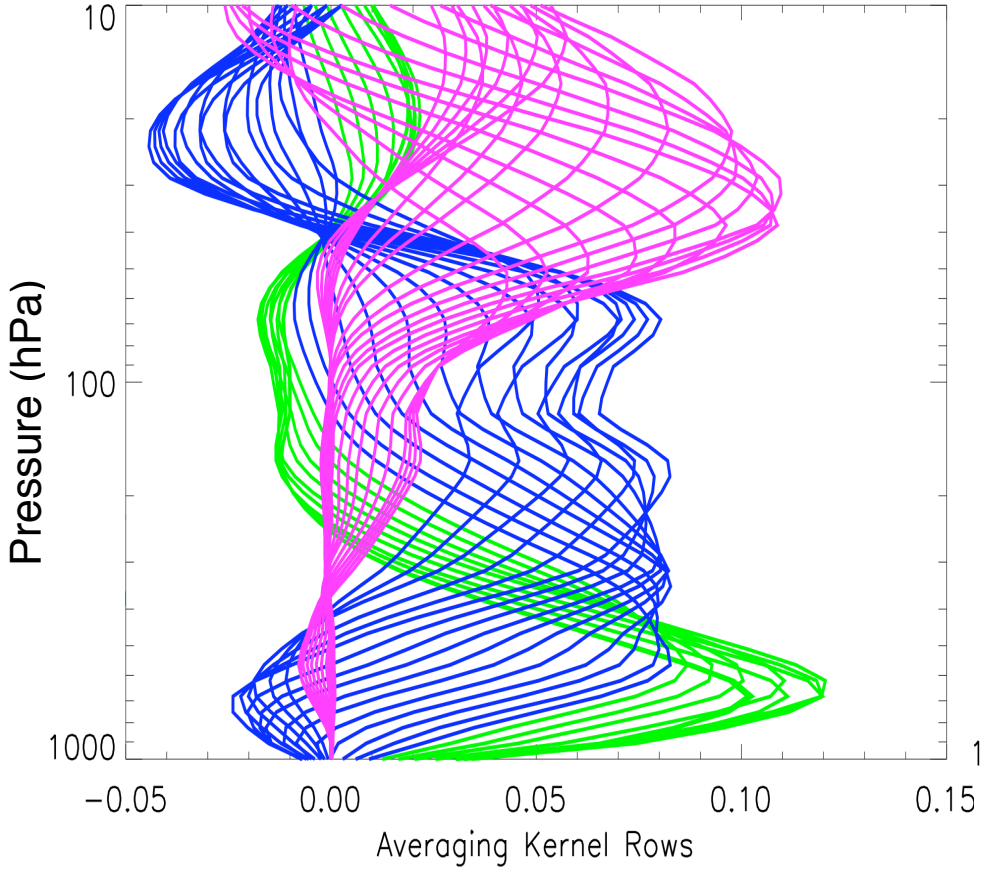
It's the spectral resolution!

Jet Propulsion Laboratory
California Institute of Technology

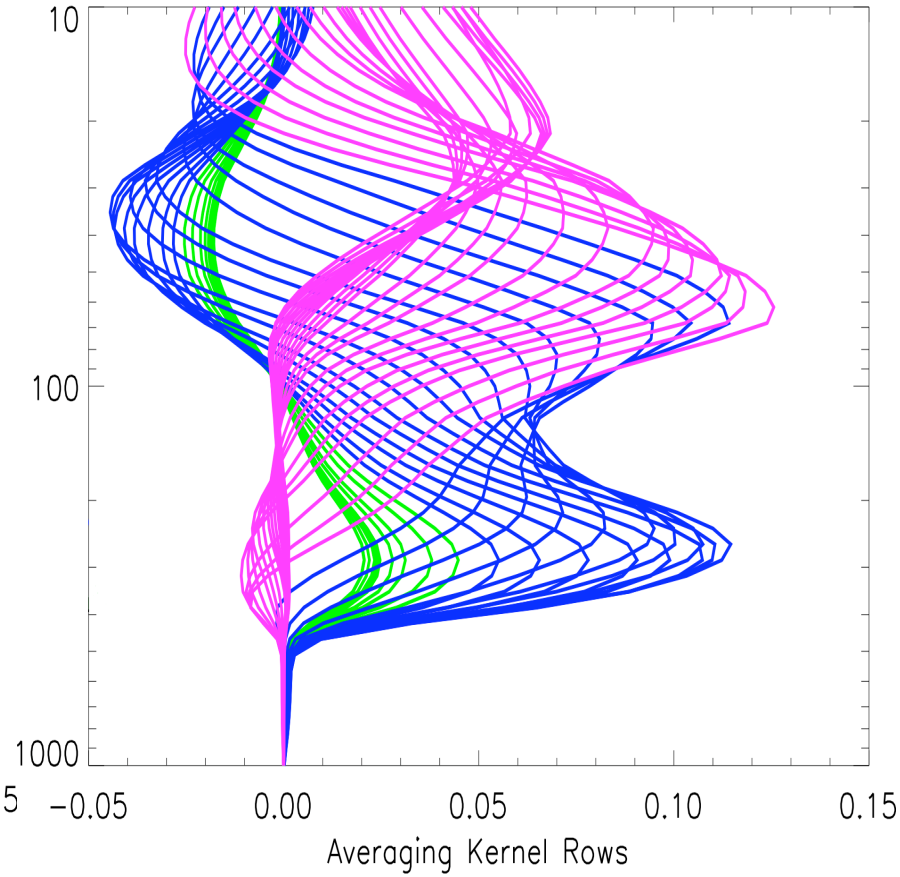








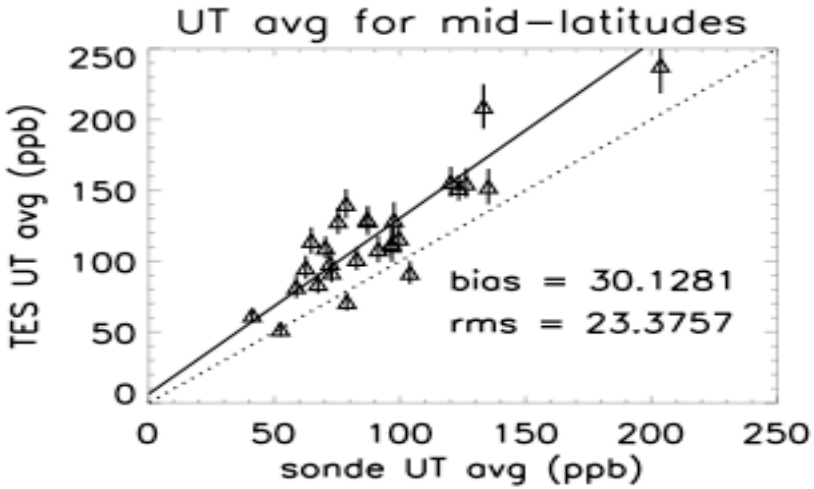
Clear (DOFS = 4.1)

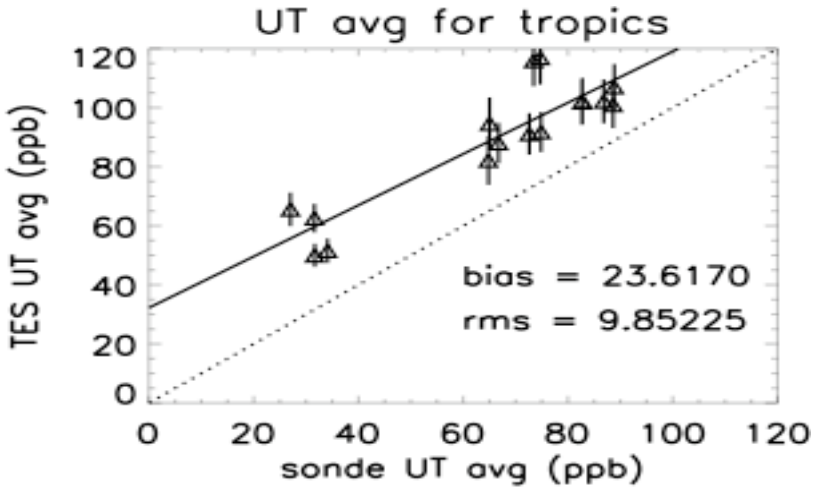


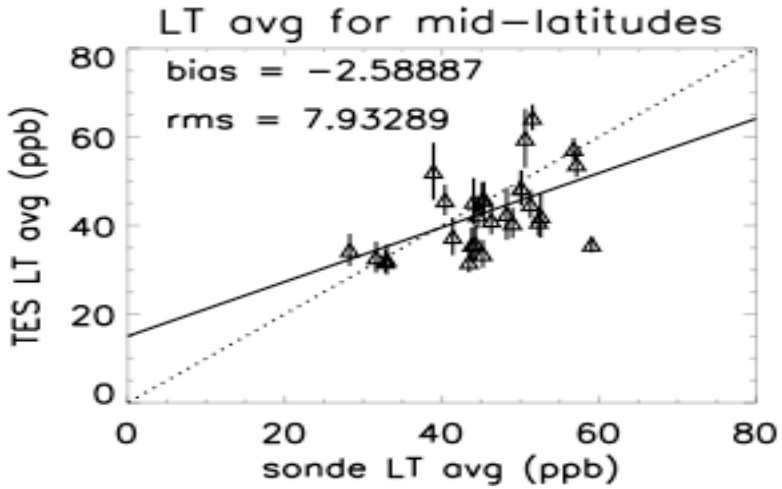
Cloud at 483 hPa (DOFS = 3.0)

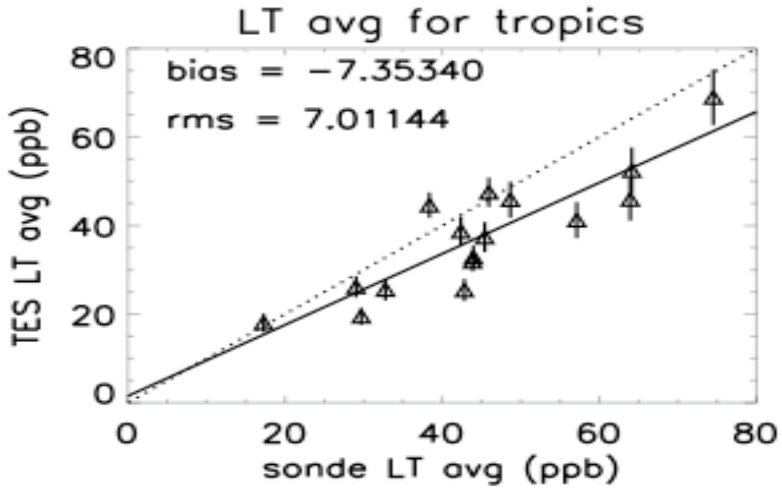
Tropospheric ozone
TES and Ozonesondes

Jet Propulsion Laboratory
California Institute of Technology





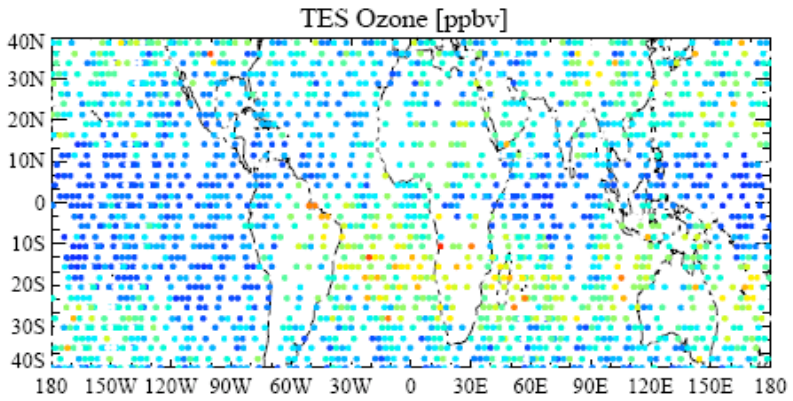


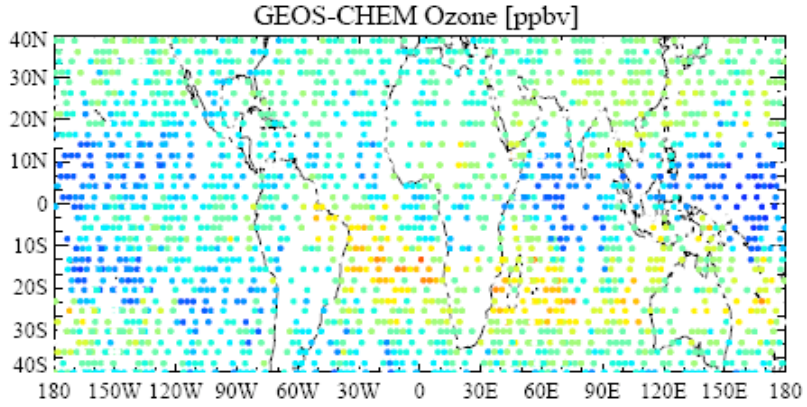


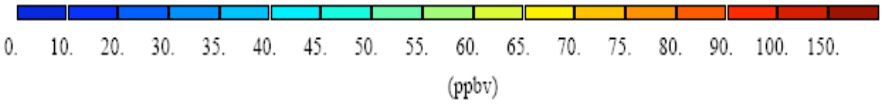
H. Worden and Logan

Comparison TES and GEOS-CHEM
1-15 November 2004, 500hPa

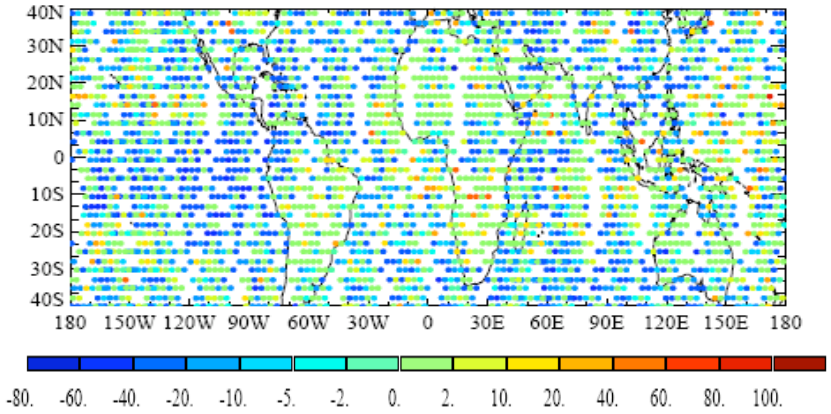
Jet Propulsion Laboratory
California Institute of Technology



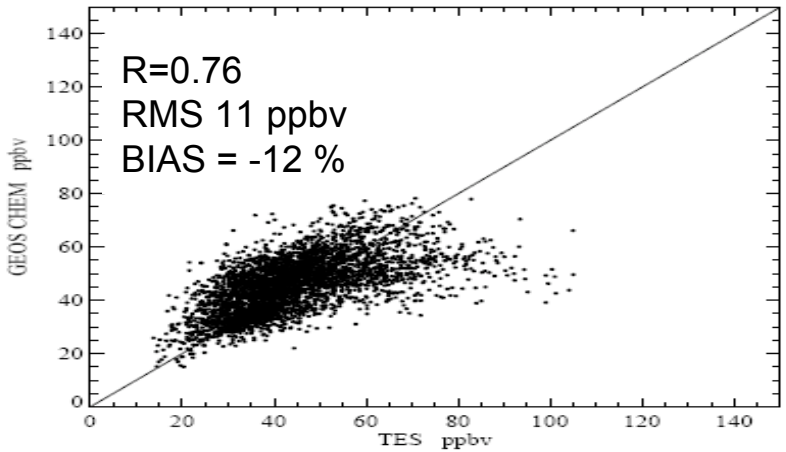




(TES-GEOS_CHEM)/GEOS-CHEM%



Tropics (30N-30S)



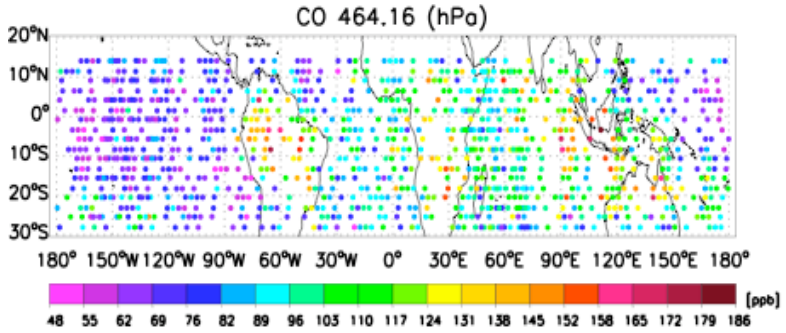
For comparison with GEOS-CHEM :

$$\ln \hat{\mathbf{x}}_{\text{model}} = \ln \mathbf{x}_{\mathbf{a}} + \mathbf{A}\left(\ln \mathbf{x}_{\text{model}} - \ln \mathbf{x}_{\mathbf{a}}\right)$$

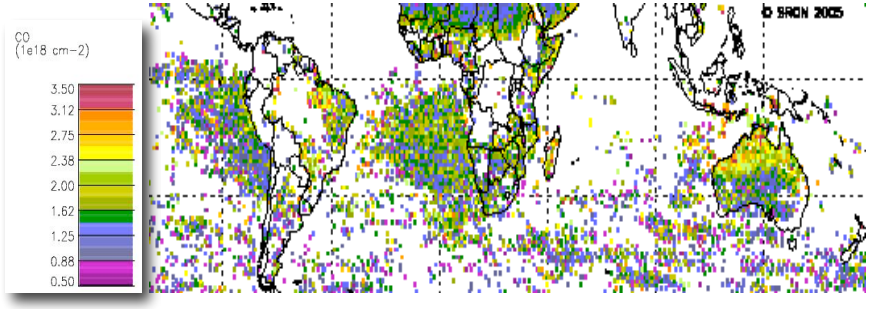
Jourdain and Li

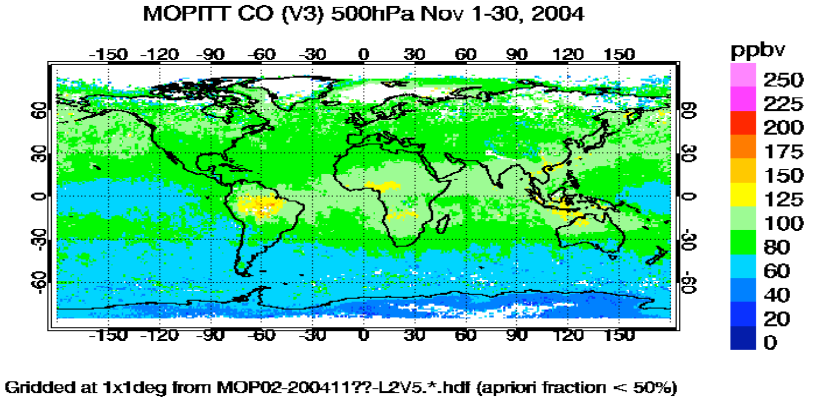
Comparison to MOPITT and Sciamachy tropospheric CO

Jet Propulsion Laboratory
California Institute of Technology



Sciamachy near-infrared CO tropospheric column estimates





Gridded at 1x1deg from MOP02-200411??-L2V5.*.hdf (apriori fraction < 50%)

MOPITT maps obtained from
http://www.eos.ucar.edu/mopitt/data/plots/mapsv3_mon.html

Sciamachy maps provided courtesy of Annemieke Gloudemans at SRON

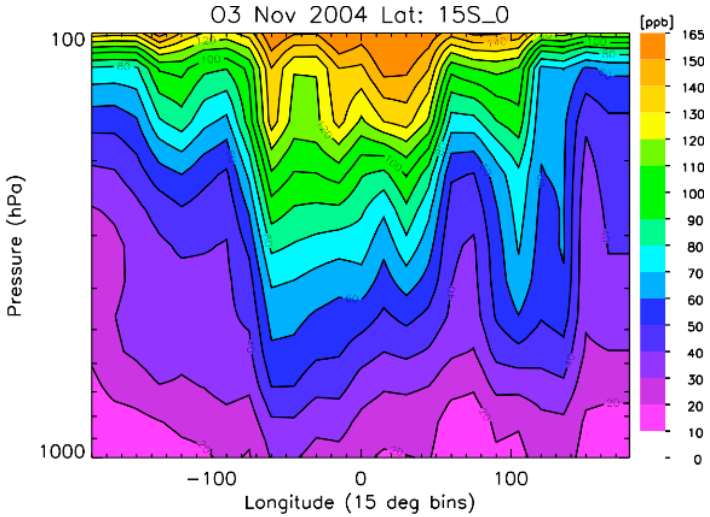
Elevated CO is observed between TES, MOPITT, and Sciamachy over South America, Africa, and Australia/Indonesia

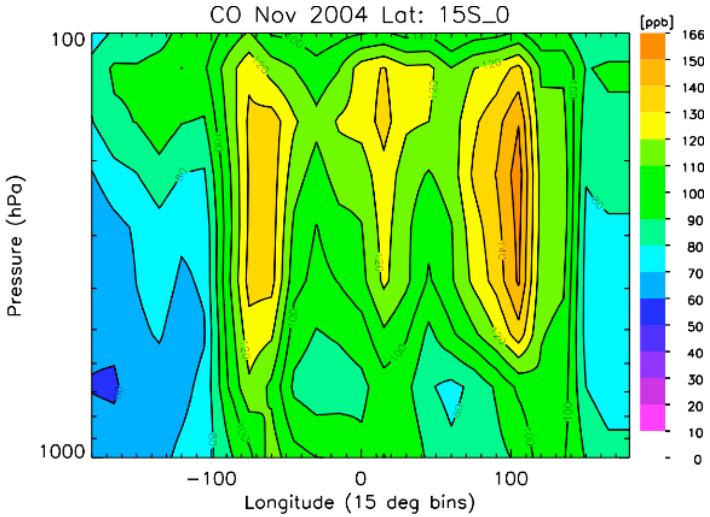
A CO “plume” is observed by TES and MOPITT from the east of Australia extending across the south Pacific

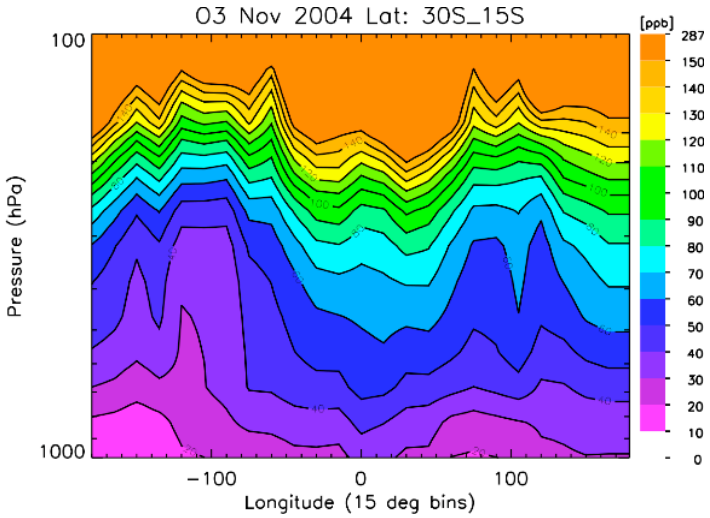
Bowman

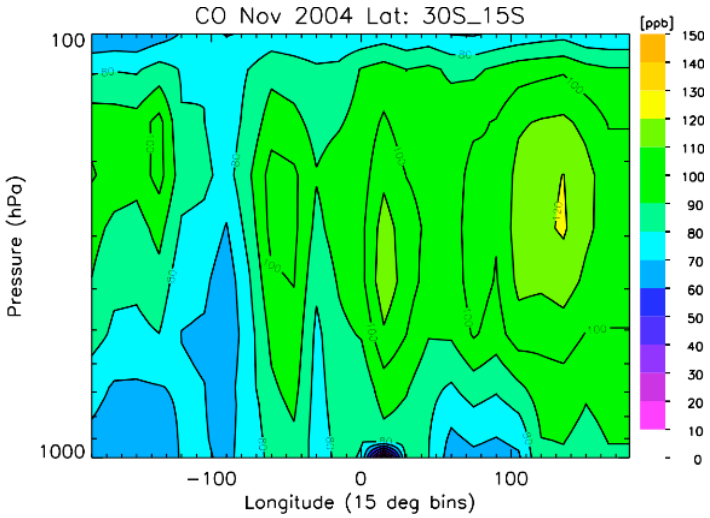
Mean Ozone and CO profiles November 4-16

Jet Propulsion Laboratory
California Institute of Technology









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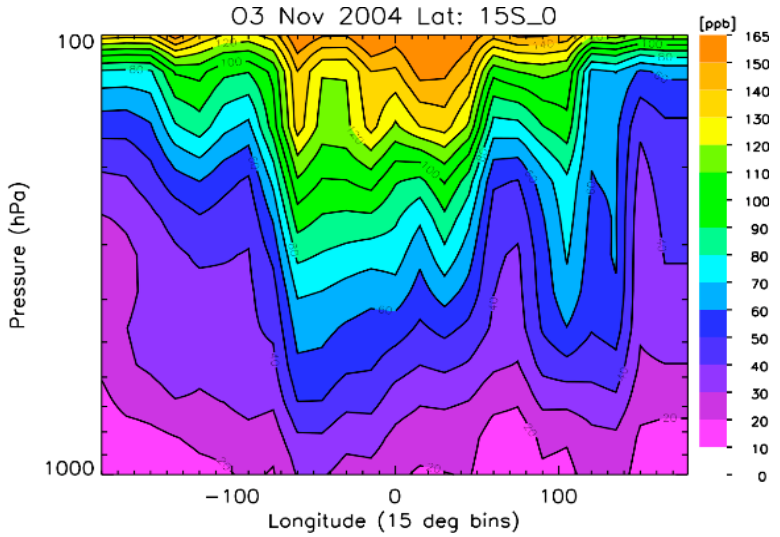
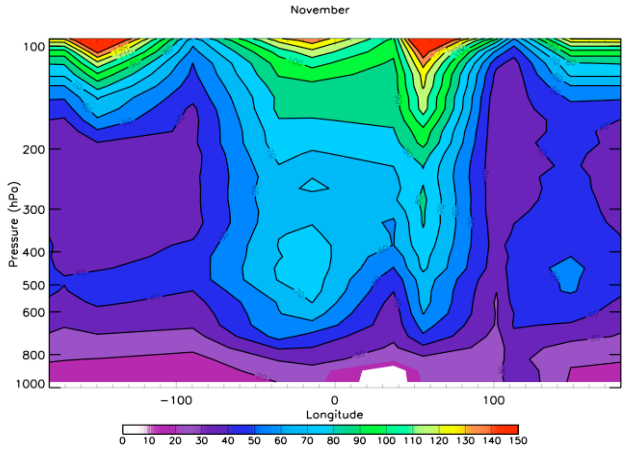
Comparison to the SHADOZ Network

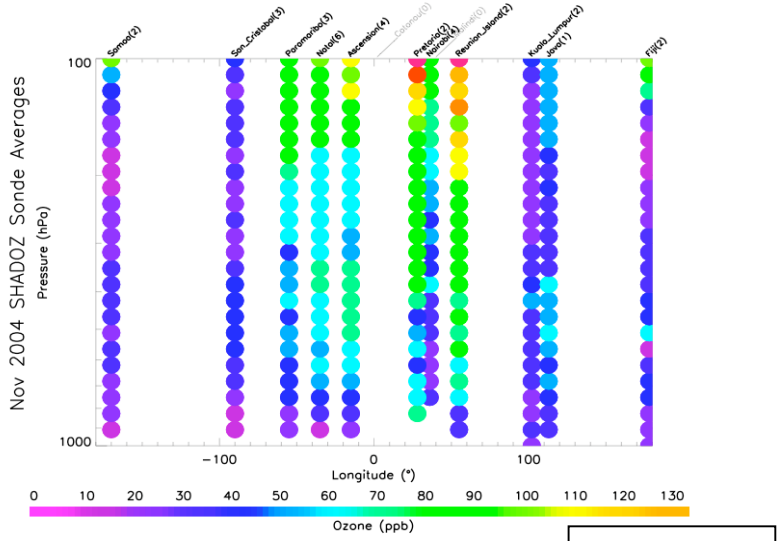
Jet Propulsion Laboratory
California Institute of Technology





Shadoz mean of ozone was calculated
from 1998-2004 for the month of November based on 11 sites
covering a latitudinal and longitudinal range of 21S to 3N

Averages for November of 2004 are also included



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Comparisons to GEOS-Chem CO

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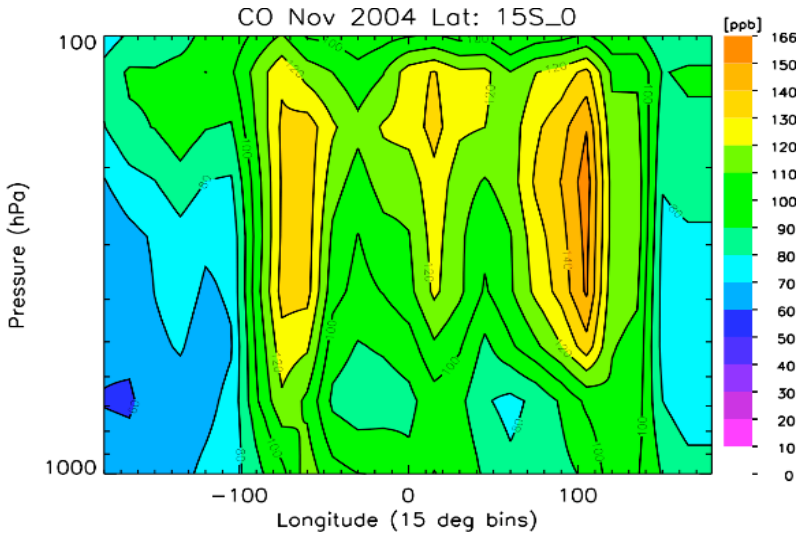
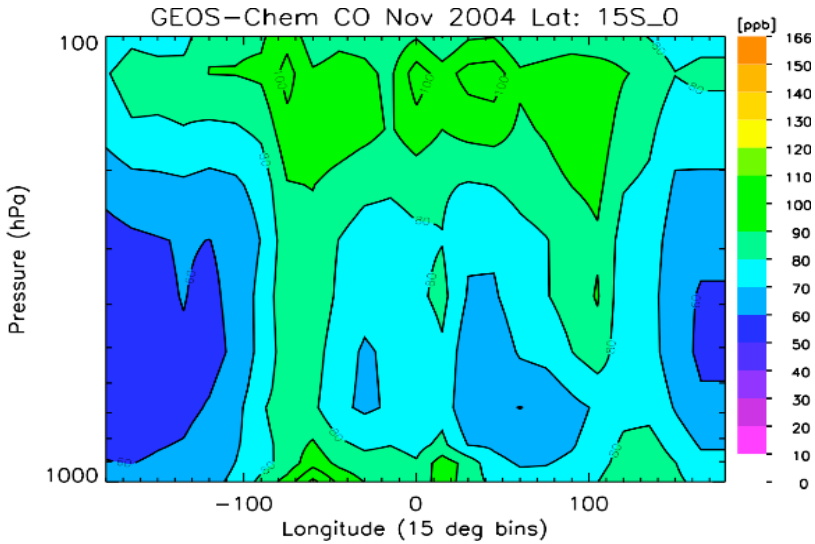
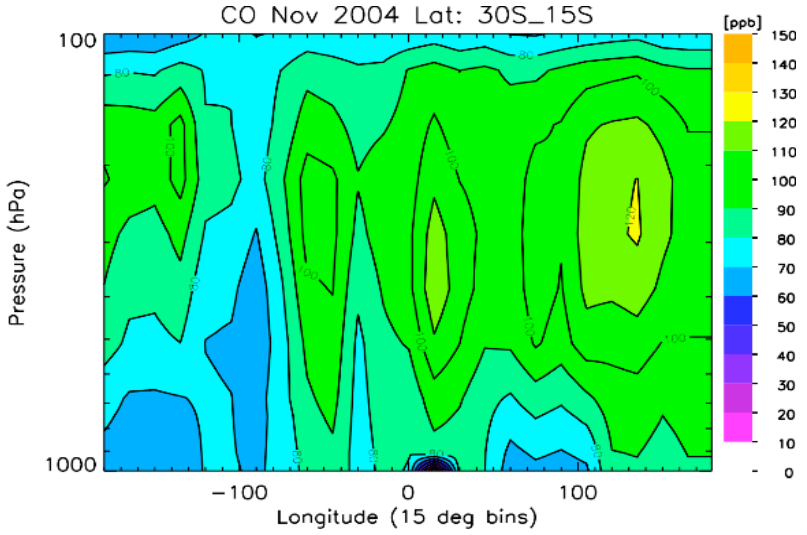
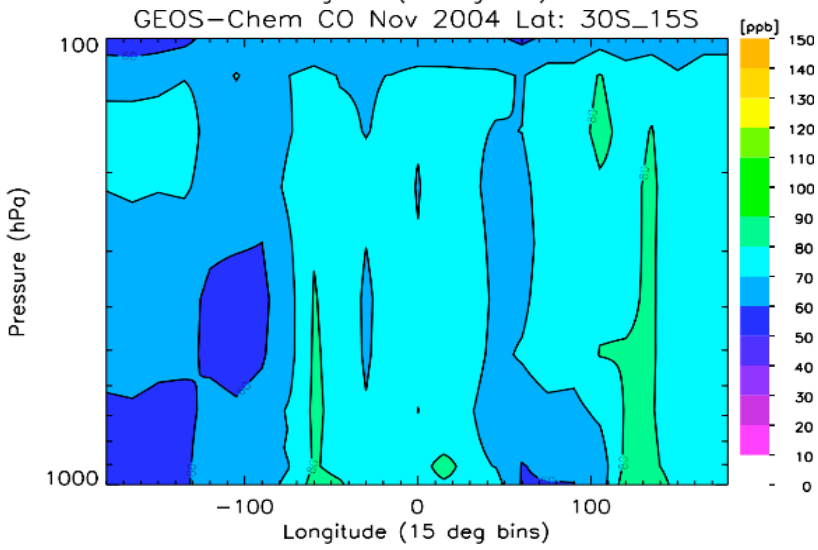
California Institute of Technology









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Comparison to GEOS-Chem O_3

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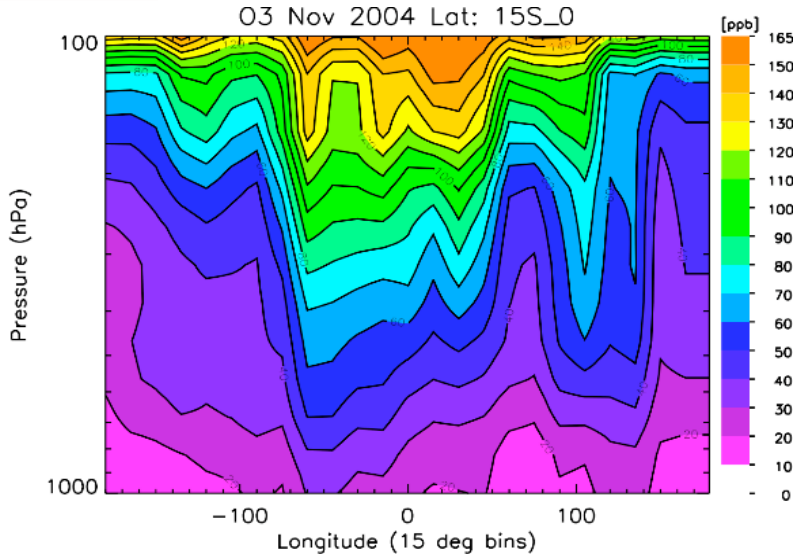

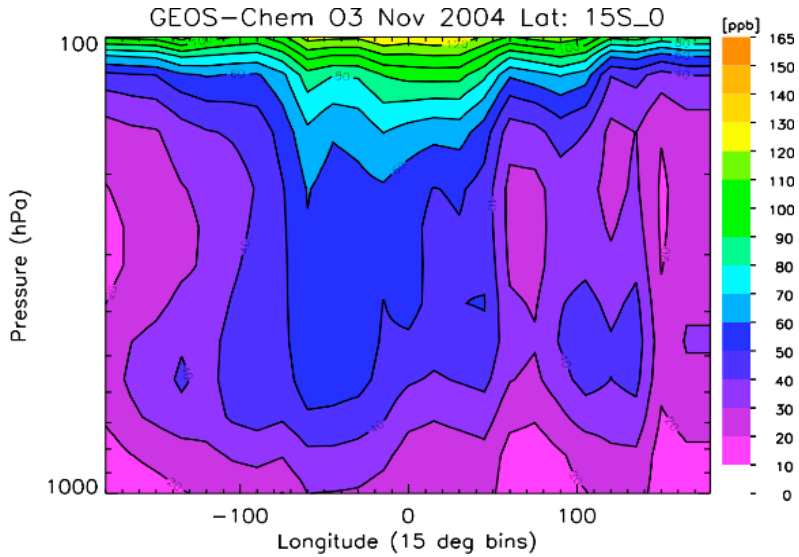

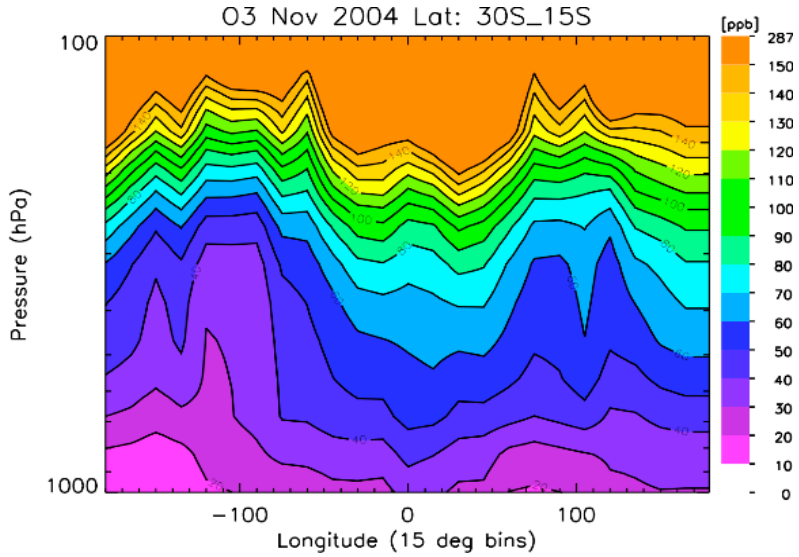

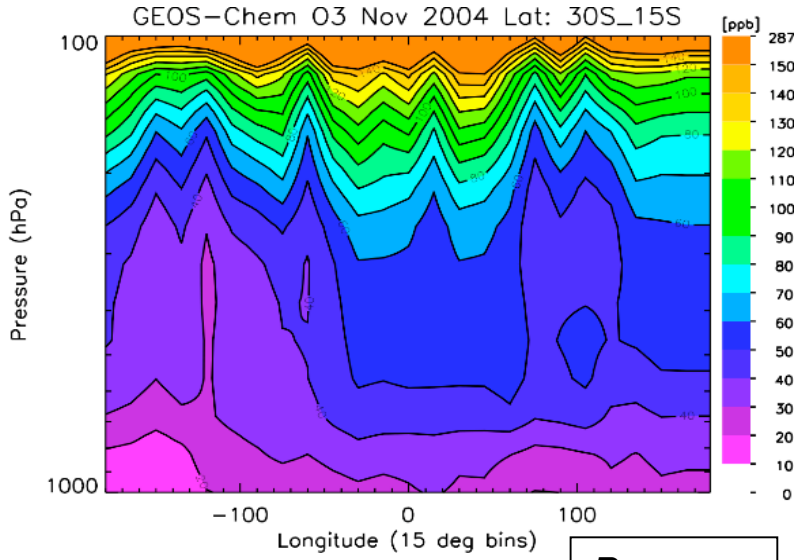

Bowman